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The Institute of Vitreous Enamellers
The Welsh Engineers' and Founders' Association
and
The Foundry Trades' Equipment and Supplies Association

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"F.C.I.R.A."

It happened that in 1930 Mr. J. Cournot presided over a meeting held in Paris to consider the formation of an information bureau for the French ironfoundry industry, and just recently he was accorded the same honour, when the Société des Ingénieurs Civils de France, in collaboration with the Centre de Recherches de Fonderie, organised a Symposium on Recent Progress in Cast Iron. This enabled Mr. Cournot to make some interesting comparisons as to the state of the art eight years ago and to-day. He ascribes 1930 as the date of the discovery of two fundamental factors in the metallurgy of cast iron. These factors are:—(1) The strength of a cast iron depends primarily on its chemical composition; and (2) the strength of a cast iron depends also on its speed of cooling.

With all due deference which one must accord to the chair, we believe that whilst these conditions might have applied to French metallurgical work, they are certainly not true of British. Well over 50 years ago, Professor Turner showed very clearly the influence of silicon on cast iron. Since that date, with a rather poor decade between 1890 and 1900, cast iron has attracted the ever-increasing attention of metallurgists of international reputation, such as Longmuir, Moldenke and Osann. Cook, Hailstone, Hurst, Smalley, Portevin, Campion and Sipp were well cognisant of the two basic factors outlined by Mr. Cournot long before 1930, and so far as this country is concerned, they were common knowledge.

If we were asked to state the major developments of the past decade or more, we should put forward the following:—(1) The control of the formation and distribution of the graphite in cast iron has become an exact science, and has ameliorated the properties of the alloy out of all recognition. (2) The introduction of alloy additions to cast iron has very considerably widened its field of application and has extended its usefulness. (3) The development of the mechanisation of foundry operations has aligned the industry with the conditions established in other spheres of manufacturing endeavour.

Probably, the object of Mr. Cournot's early remarks was to provide a convenient peg upon which to hang the balance of his excellent speech. He dealt at some length with the work of the French cast iron research association, and covered its activities from its inception in July, 1931, to December, 1937. It seems that during this period the association received 4,556 technical inquiries, necessitating 795 visits to foundries and the analysis of 4,539 samples. It is interesting and illuminating to note that the major inquiries of the French foundry industry referred to the strength and compositional control of cast iron (930 inquiries) and to the control of production (910). If the former were to include heat and corrosion resisting cast irons and the like, then the figure would have attained the high total of 2,100—a figure approximating half the inquiries received. Such factors as the examination of foundry wasters and sand problems are by comparison extremely low.

These figures cannot be related to a fixed membership, as the French association is financed by a group of pig-iron producers, and the service to the foundry industry is definitely free. The work of the "Centre" was defined by Mr. Cournot in the following terms:—The outstanding endeavour of the "Centre" is to assist in the production of good castings of regular composition and mechanical properties at a reasonable cost price. Theoretical considerations only come into the picture in the case where correspondents show interest either for their personal use or better to understand and apply the information submitted. Researches of a scientific character are also carried out, but here again always on subjects destined to solve pressing foundry problems, improve quality or cheapen production. Thus, in six years more than ninety research reports of varying importance have been published. These include the rationalisation of chill test-pieces; a study of the change of composition by iron in its passage through the cupola; the determination of formulæ and the best methods of making special irons. From these relatively simple subjects, work has been in progress on such questions as structural changes in relation to oxidation and sulphuration and problems to be associated with heat-treatment.

French foundrymen are indeed to be envied, as these free services cost several tens of millions of francs each year. Naturally, it is impossible to make a calculation of just what this means, but, fortunately, Mr. Cournot has solved this problem for us by stating that the annual budget of the British Cast Iron Research Association is of the order of a million francs per annum. Thus, the French foundry industry is subsidised by a group of pig-iron producers for its research work to a ten-fold extent compared with that available in the United Kingdom, even though in our case there is included the Government subsidy.

Reinforced Concrete Air-Raid Shelters

Air-raid shelters which are now being manufactured by the Stanton Ironworks Company, Limited, of Nottingham, and designed to meet Home Office recommendations, are constructed of spun concrete pipes 7 ft. 6 in. in dia. and 4½ in. thick, specially reinforced to withstand shocks. The standard size of shelter provides accommodation for 50 persons, but larger or smaller sizes are available. The shelter may be buried at any required depth and covered with concrete, earth, sand, or a combination of these materials in successive layers.

Alternative types of entrance are available—a vertical shaft and ladder, or a flight of steps leading to a small air-lock chamber. All doors are gas-tight, and whilst people are entering the air-lock chamber from outside the shelter, the door into the main chamber remains closed. When all have entered, the outer door is closed, and when contaminated clothing (which may be stored in the air-lock chamber) has been removed, the door between the air-lock and the main chamber is opened. A wash-basin and first-aid box are provided in the air-lock compartment.

The available headroom in the main chamber is 6 ft. 8 in. Provision has been made for a constant supply of filtered fresh air, and for this purpose a hand-driven air pump is provided to filter air drawn in from outside. Pressure in the inner chamber is maintained at a slightly higher level than that of the outside atmosphere, as a further precaution against the entry of gas. An exhaust valve prevents air pressure within the shelter from becoming too high and provides a means of exit for stale air. Drainage to a sump at one end of the shelter is provided.

Two types of seating are available, one type having cupboards under the seats for the storage of sand, picks and shovels and other tools, the other having open storage compartments behind the seats. Other equipment includes vessels for drinking water, cupboards for the storage of food, electric torches and gas masks, and fire extinguishers. Electric light will be provided from dry batteries. In addition an earth closet is provided at one end of the inner compartment.

The Stanton Ironworks Company are themselves installing eight of these shelters to provide protection during air-raids for key-men who must remain at their posts, a purpose for which a shelter of this type is admirably suited. The shelter may be in telephonic communication with headquarters, and a wireless receiving set installed as a further means of keeping in touch with the outside world.

Correspondence

[*We accept no responsibility for the statements made or the opinions expressed by our correspondents.*]

I.B.F. Golf Competition

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—It is with a good deal of pleasure that I am able to announce that Mr. E. A. Phillips, of Grimsby, has kindly presented a small cup to each of the runners-up in the recent golf competition held at Matlock. These cups, together with the cup and silver tankard given by Major T. G. Bird and Mr. J. E. Hurst respectively, will be presented to the winners during the Bradford Conference. The winners of Mr. Phillips' cups are Mr. A. G. Robiette and Mr. F. A. Wilson.

I would like to take this opportunity of stating that without the assistance and co-operation of Mr. R. Stiles and Mr. A. G. Robiette the competition would certainly not have been carried through so successfully. They have given much of their time in promoting the competition, and I hope that, if the Council of the Institute consider that a golf competition should be an annual event, then these two gentlemen will be asked to serve again on the committee. I would also like to express my sincere appreciation of the help given by Mr. J. Gardom and Mr. D. H. Wood.

With the experience gained at Matlock this year, I hope that a competition will be organised next year and that this will prove even more successful.—Yours, etc.,

JAMES BELL.

3, Cherry Street,
Birmingham, 2.
June 9, 1938.

The Bradford Conference

The 35th Annual Conference of the Institute of British Foundrymen, attended by some 370 delegates, was opened on Tuesday at the Bradford Technical College under the Presidency of Mr. C. W. Bigg. Mr. Joseph Hepworth, J.P., M.P., was installed as President, and Mr. W. B. Lake, J.P., and Major R. Miles of Middlesbrough, were elected to the positions of senior and junior Vice-President. In the evening the members and their ladies were the guests of the Lord Mayor and the Lady Mayoress at a civic reception held at the Cartwright Memorial Hall.

Yesterday (Wednesday), the Institute was accorded a civic welcome by the Lord Mayor of Bradford and he presented the E. J. Fox Medal to Mr. J. E. Hurst and the Oliver Stubbs Medal to Mr. S. E. Dawson. After Mr. Hepworth had read his Presidential Address, a number of technical Papers were submitted, those dealing with non-ferrous foundry practice being dealt with in a separate session.

Yesterday afternoon a number of representative works in the locality were inspected and in the evening the annual banquet was held.

A full report of the Conference will be published in a special issue of the *Journal* next Thursday. This will also contain illustrated descriptions of all the works which have been visited.

Catalogue Received

Electric Motors. The General Electric Company, Limited, of Magnet House, Kingsway, London, W.C.2, have prepared an essentially utilitarian catalogue of their standard range of a.c. and d.c. electric motors up to 50 h.p., together with their appropriate starters. This catalogue can be suspended from one corner, it is perforated for filing, and there are thumb-cuts for facilitating quick reference.

Random Shots

It is a sad thought that with the development of mechanisation in the foundry, one type of workman is inevitably dying out. He was the sort of individual who had character and personality to which he could give free vent in a work still largely a craft, in the days when a man could be a man and not simply a machine minder. Most old-established foundries could unfold tales of men who used to work for them who, if bad lads at times, were real characters, whilst also being sincerely devoted to their work. Such a man worked for thirty years with Tilghman's Sand Blast Company, Limited, and was known as Charlie, the Man with the Bowler Hat. A good story is told of Charlie, who had been away from work for a day or two. During his absence a large mould about 3 ft. deep had been cut in the floor by the foundry door. Charlie came into the dark shop early next morning, and, not seeing the change, stepped straight into the mould, together with dinner basket, knife, spoon and etceteras. There being no one to help him, he floundered about, groping for his dinner pots, but managed eventually to get out. How could he meet the mate who owned that job? Charlie was too smart a bird to be caught like that, so he went outside and made a fresh arrival half an hour late, and just in time to join the rest of the foundry staff who were rating the apprentices for skylarking again.

* * *

Mr. James Forest, who has just retired from John Stein & Company, Limited, should be a happy man indeed, and the Compleat Angler withal. With two easy chairs and a fishing rod he makes sure of pursuing his favourite sport in real comfort and complete quietude. One presumes, of course, that whilst he will undoubtedly take one chair with him, he will leave the other at home for the better comfort of that proverbial disturber of man's peace.

* * *

Molybdenum may be invaluable in the foundry for improving cast iron, but, judging by the experience of certain Somerset farmers, it is no good for cows. According to a contemporary daily, molybdenum is "a whitish mineral of an acid-forming nature, containing strong constituents of sulphur and graphite." No wonder the poor cows died!

* * *

Last week's business story having been proclaimed a chestnut, a newer one on the same theme has been offered by Mr. Barrington Hooper:—"A Gentile is a man who buys things retail." As brevity was ever the soul of wit, he is handed the palm forthwith!

* * *

A wealthy business man managed his affairs so badly that eventually he went bankrupt. When examined as to how he spent his income, which was in the region of £30,000, he analysed it thus:—

"I spent about £10,000 a year on various sweethearts; £10,000 on champagne, cigars and racing. As for the other £10,000, well, I guess I must just have wasted it!"

* * *

What a world this is when even the six-year-olds are "blinded by science," as the popular phrase has it. "When you go on your cruise, Mummy," said one young hopeful, anxious about his mother's health, "you must catch some hydrogen and put it in a boxogen to bring home with you. That'll make you better."

"MARKSMAN."

Aluminium Casting Alloys*

By G. GÜRTLER†

[GERMAN EXCHANGE PAPER.]

A study of the development of aluminium casting alloys in England and Germany shows that in both countries, as also in other countries, three very similar main types of alloys are in use. These are the alloys with the principal additions of Cu, Si or Mg. According to the demands which they have to meet, the alloys also contain further additions of a second of the above elements and/or Zn, Ni, Fe, Mn, Ti, etc.

In England, alloys on an Al-Cu basis with additions of Ni and Mg of the type of "Y" and "RR" alloys are largely employed for high-grade castings, whereas in Germany greater importance has been placed on developing the Al-Si alloys which possess good casting properties, are rendered age-hardenable by an addition of Mg and represent valuable constructional materials. These alloys, together with those of the Al-Mg group with various additions of Si and Mg, have the further advantage that their resistance to corrosion is far superior to that of alloys containing copper. In addition to these three main groups of alloys, there are also a number of special alloys which will be discussed later.

Some of the foundry and metallurgical problems which have been dealt with in recent times in Germany, and the knowledge thereby acquired, will be considered in this Paper, the author's intention being to discuss more particularly those alloys which are not so well known in England, and he will thus perhaps be able to throw out a few suggestions.

Gases in Aluminium

The problem of the removal of gases, especially hydrogen, from molten aluminium still plays an important part in melting and foundry practice. It is known that aluminium and its alloys absorb gas in quantities which increase with increasing temperature and pressure.[1 2] During melting, the presence of water vapour and hydrogen, and to a lesser degree also other gases, in the crucibles or the brickwork of the furnace and in the furnace atmosphere, generally results in an absorption of gases which, with the changes in temperature and concentration occurring during the subsequent course of melting and pouring, leads to a supersaturation of the melt with gas.

The first problem of an effective removal of gas is to establish an equilibrium as completely and as rapidly as possible between the gassed melt and an atmosphere which is free from gas or contains only inert gases. This is accomplished, for example, by lowering the temperature very slowly and re-heating rapidly,[3] by passing inert or chemically active gases through the molten metal,[3 4] and by the use of salts containing in particular chlorine and fluorine.[5 6 7] The most effective method is a combination of salt treatment and allowing to stand, during which time the temperature need not be allowed to fall. An example of a laboratory experiment employing relatively small amounts of molten metal will illustrate this point.

DIPL.-ING. G. GÜRTLER.

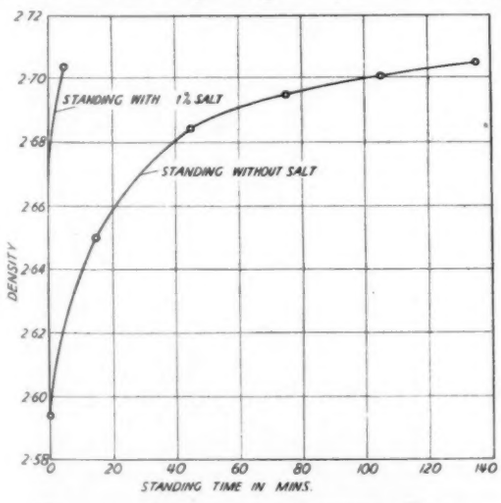


FIG. 1.—RESULTS OF ALLOWING PURE ALUMINIUM TO STAND WITH AND WITHOUT SALT.

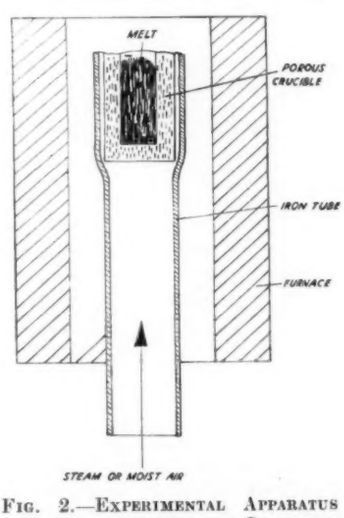


FIG. 2.—EXPERIMENTAL APPARATUS FOR INVESTIGATING THE INFLUENCE OF THE MOULD.

A melt of pure aluminium (99.5 per cent.) was gassed at 750 deg. C. in an electric furnace by passing hydrogen through it, and while the temperature was maintained, samples were taken at various intervals and their density after solidifying in sand was determined. A second melt was gassed at the same temperature in the same way, and after a first sample had been taken, about 1 per cent. of a mixture of sodium chloride and sodium fluoride was stirred in, a further sample being poured immediately after the salt treatment. The results of these two experiments are shown by the curves in Fig. 1, and indicate clearly the acceleration of degasification by the salt treatment. With the larger quantities of metal used in the foundry, degasification naturally requires a longer time. It is important to have an atmosphere which is perfectly free from hydrogen, particularly if the pouring temperature is to be high. In experiments with Al-Si alloys, for instance, it was observed that when the metal was allowed to stand in a gas-heated furnace which had been heated up and then put out of operation at the commencement of the standing experiment, it was impossible to secure complete degasification. The experiment was successful only when a container was provided in the furnace, the crucible being placed in the container and carbon dioxide being passed through the container as protective gas during the standing period. Such dangers are not so great in the electric furnace. In the author's opinion, the best explanation of the effect of the salt treatment in accelerating the liberation of gas is that furnished by Scheuer, according to whom the oxide film forming on the surface of the melt and preventing the establishment of the gas equilibrium is destroyed by the salt, thus resulting in a better diffusion of the gases.

Supersonic Vibrations

In the case of aqueous solutions, it has been observed that a very effective liberation of gas is produced by the action of supersonic vibrations. It is doubtful, however, whether molten metal can be degassed by supersonic vibrations, although it may indeed be assumed that gases in the state of supersaturated solution could be liberated and would escape in the form of minute bubbles, but the practical solution of the problem is very difficult and the author is not aware of any industrially and economically applicable method of introducing the necessary energy into the melt and transmitting such energy through it with the least possible loss.

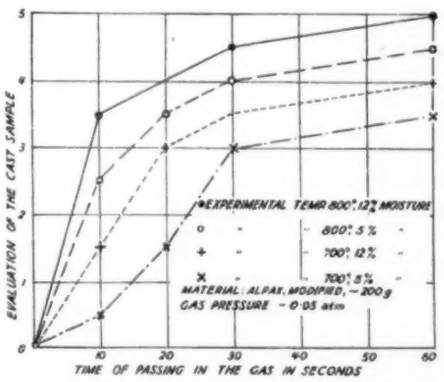


FIG. 3.—VARIATION OF GASSING WITH TEMPERATURE, TIME AND AMOUNT OF MOISTURE.

What Happens in a Sand Mould

The second and more difficult problem for the foundryman is to prevent the metal from reabsorbing gas while the mould is being filled. The moisture in the mould—in aluminium casting green-sand moulds are usually employed—is evaporated and is dissociated by the molten metal into hydrogen and oxygen. Even in the case of a highly permeable sand mould, atomic hydrogen in a relatively high concentration will appear in the boundary zone between the sand

D

* Paper presented on behalf of the Technischer Hauptausschuss für Giessereiwesen, Düsseldorf, to the Non-Ferrous Symposium at the Annual Conference of the Institute of British Foundrymen at Bradford.

† Dipl.-Ing. Scientific Officer to the Metal Laboratory of the Metallgesellschaft A.G., Frankfurt a.M., Germany.

and metal. This nascent hydrogen is very active and gases the metal so rapidly that the equilibrium between the melt and air cannot be established rapidly enough in the time elapsing before solidification. Even using dry moulds, it has been possible to observe in the foundry an increase in the gas content with certain alloys.

The following experimental apparatus was

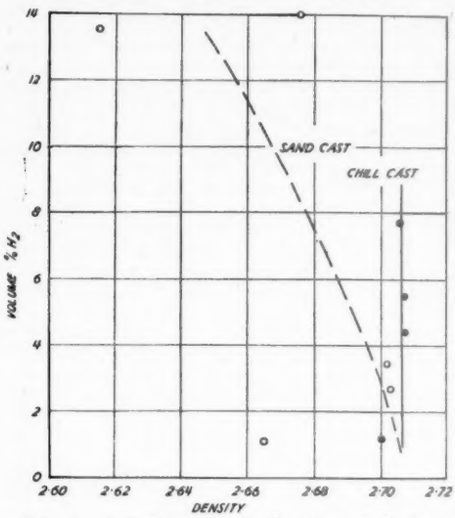


FIG. 4.—GAS CONTENT AND DENSITY IN SAND-CAST AND CHILL-CAST SPECIMENS.

devised to provide a picture of the occurrences taking place in the mould:—

A porous crucible representing the mould and containing about 200 grms. of a Silumin (Alpax) melt, modified by means of sodium, was placed in a vertical tube standing in a cylindrical laboratory electric furnace. The metal was then heated to 700 and 800 deg. C. and air saturated with water vapour at 30 and 50 deg. C. was passed through the tube and the porous crucible at a moderate pressure (about 0.05 atm.), corre-

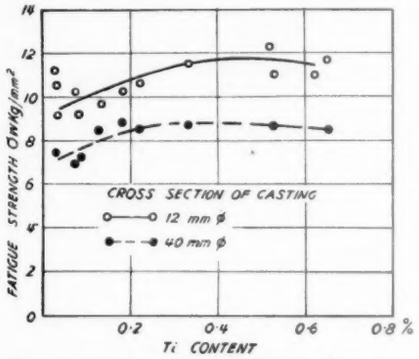
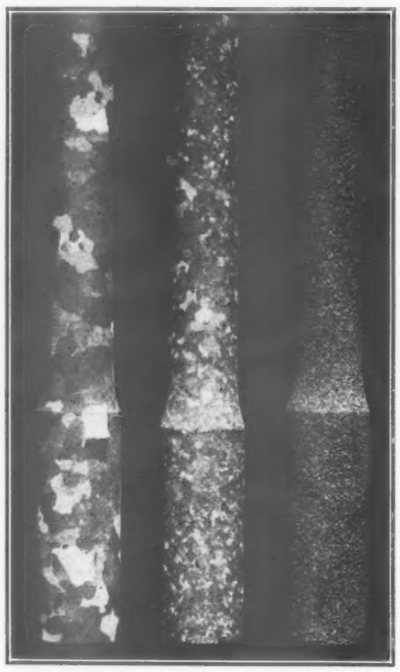


FIG. 5A.—VARIATION OF FATIGUE STRENGTH OF ALPAX-GAMMA WITH 10 PER CENT. SI WITH THE TI CONTENT.

sponding to a moisture content of 5 and 12 per cent. respectively. At the same time, the melt was stirred with a rod in order to imitate flow along the walls of the mould. Fig. 2 shows the experimental apparatus, and Fig. 3 the results of an experiment with modified Alpax (Silumin).

The evaluation of the results was made on small samples cast in an open carbon mould. The character of the surface of the samples—the gas, in escaping through the surface, leaves a crater of about pinhead size—is a fairly reliable measure of the degree of gas-content, as was shown by comparative measurements of the density and gas determinations by extraction *in vacuo*. Zero denotes a perfectly gas-free specimen, five a strongly-gassed specimen. It is always possible to effect a gradation according to a series of six samples of increasing gas content taken as a standard.[8] The experiment shows the harmful effect of even slight quantities of moisture and the importance of keeping the pouring temperature as low as possible. In many



0.03% Ti. 0.2% Ti. 0.5% Ti.

FIG. 5B.—VARIATION OF GRAIN SIZE OF ALPAX-GAMMA WITH 10 PER CENT. SI WITH THE TI CONTENT.

cases, the foundryman will not want to forgo the rapid cooling effect of the green mould, and therefore the only means at his disposal will be the shortening of the path of flow, and hence the reduction of the time of flow, and the possibility of lowering the pouring temperature.

Rapid cooling even has a favourable effect, since in the case, for example, of chill castings, it is possible even with gassed melts to produce sounder castings than in the case of casting in sand. This means that, when solidification is

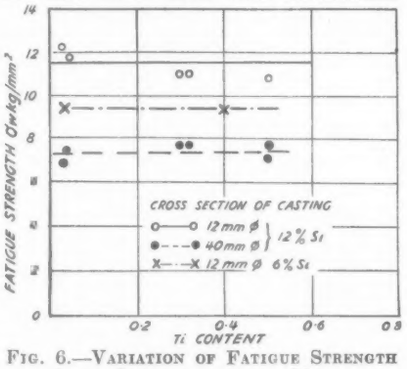


FIG. 6.—VARIATION OF FATIGUE STRENGTH OF ALPAX-GAMMA CONTAINING 12 PER CENT. AND 6 PER CENT. SI WITH THE TI CONTENT.

rapid, the metal is able to retain in solution larger quantities of gas than correspond to equilibrium. Measurements of the density and the gas-content by hot vacuum extraction of bars (about 1 in. diameter and 8 in. length) cast simultaneously in sand and chill moulds from melts of different gas contents show that in the case of the sand-cast bars, the density diminishes with increasing gas content, but remains almost constant in the case of chill-cast bars (see Fig. 4).

The absolute quantities of gas, moreover, differ according to the method employed for determining the gas. The largest amounts have been found by Chaudron[9] in an electric discharge tube in which the specimen whose gas content is to be ascertained is exposed to a bombardment by

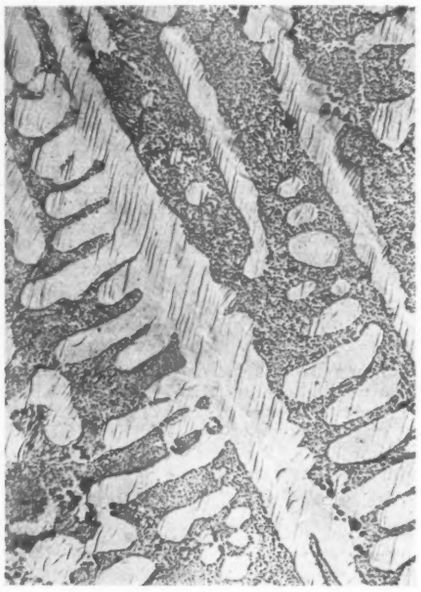


FIG. 7.—ALUMINIUM DENDRITE WITH SLIP BANDS. × 200.

ions and electrons. The foundryman, however, is not immediately interested in the absolute quantities of gas contained in the metal, but he is

FIG. 8.—ALPAX-GAMMA WITH 10 PER CENT. SI AND 0 PER CENT. TI. × 40.

only concerned with the gas which is liberated during solidification and produces blow-holes and gas cavities.

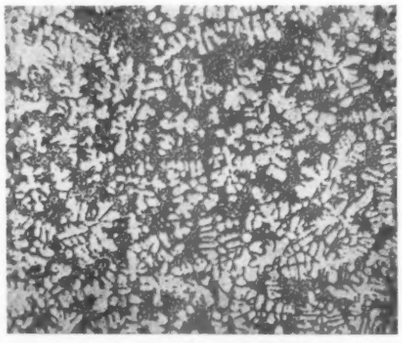


FIG. 9.—ALPAX-GAMMA WITH 10 PER CENT. SI AND 0.4 PER CENT. TI. × 40.

The author will now discuss some metallurgical questions and results which should also interest the foundryman.

Influence of Titanium

To begin with, a few remarks on the influence of small additions of Ti to cast alloys. Starting from the observation that in the case of the "Y" alloy with a very coarse macro-grain, shrinkage cracks appeared along the boundaries of the large grains, an attempt was made to eliminate this phenomenon by making use of the well-known grain-refining effect of Ti, a

FIG. 10.—ALPAX-GAMMA WITH 12 PER CENT. SI AND 0 PER CENT. TI. × 40.

successful result being achieved with an addition of 0.2 per cent. titanium.[10] In this connection, it was of interest to see whether the fatigue strength of cast aluminium increases with the increase in fineness of the grain. Gough,[11] it is true, failed to find any influence on the grain boundaries in the case of aluminium crystals, but Templin[12] observed an increase in the fatigue strength of about 20 per cent., by the refining of the macro-grain in the case of rolled material.

Endurance tests on cast bars of 12 and 40 mm. diameter of "Y" alloy and Alpax-Gamma having a silicon content of 10 per cent. showed a fatigue strength increasing with increase in fineness of the grain.[10 13] The optimum Ti contents lay in the range of 0.3 to 0.5 per cent., an increase in the fatigue strength of 15 to 20 per cent. being observed (see Figs. 5A and B). The explanation that an increase in the number of grain boundaries would result in an increase in

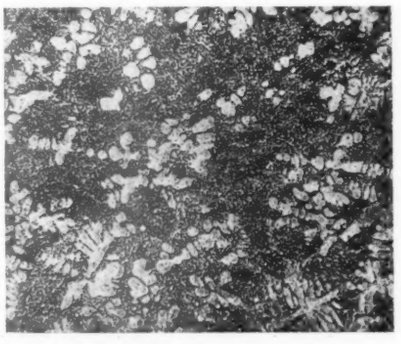


FIG. 11.—ALPAX-GAMMA WITH 12 PER CENT. SI AND 0.4 PER CENT. TI. × 40.

the fatigue strength appeared therefore to be correct. When the tests were extended to Alpax with 12 per cent. Si and 6 per cent. Si, however, no change in the fatigue strength was found, despite the same grain refinement (Fig. 6).

Investigation of the fracturing process showed, in agreement with Gough and his collaborators,[14] that fracture is initiated by cracks along the slip planes in the aluminium primary crystals. Fig. 7 shows an aluminium primary crystal with slip bands produced by stretching. The more extensive these slip planes are, i.e., the larger and more continuous the aluminium primary crystals, the more pronounced will their notch-effect be when subjected to repeated stressing. An alloy in which this unfavourable form of the primary crystals has been altered by the addition of titanium, this metal increasing the number of primary crystals and diminishing their size, as is shown in Figs. 8 and 9, may exhibit an increase in fatigue strength, while, on the contrary, no improvement occurs when the shape of the aluminium dendrites is only immaterially altered, as is shown in Figs. 10 to 13 in the case of an Al-Si alloy with 12 and 6 per cent. Si.[15]

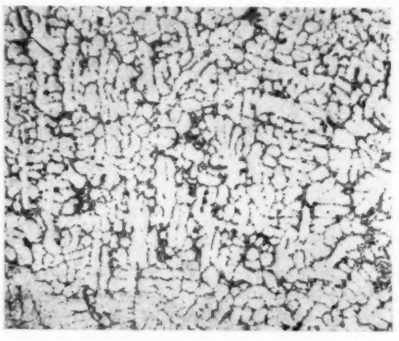


FIG. 12.—ALPAX-GAMMA WITH 6 PER CENT. SI AND 0 PER CENT. TI. × 40.

Age-Hardening by Mg_2Si

In a number of cast alloys used in Germany, advantage has been taken of the strength-increasing effect of the compound Mg_2Si attainable by heat-treatment, in the same way, for instance, as that of $CuAl_2$ in the case of the Al-Cu alloys. In alloys containing several per cent. of Mg, the solubility of the Mg_2Si is almost entirely prevented, while excess of Si only has a slight influence on the solubility of Mg_2Si. Thus, for instance, in the case of the Al-Si alloy, Alpax-Gamma with an addition of 0.5 per cent. Mg, a considerable increase in tensile strength, yield point and hardness is secured by annealing at 530 deg. C. and quenching in water, followed by heating for 20 hours at 150 deg. C.[13] (Fig. 14). In this connection, the behaviour of the fatigue strength is remarkable, as it is not affected by the Mg_2Si content like the static properties, this

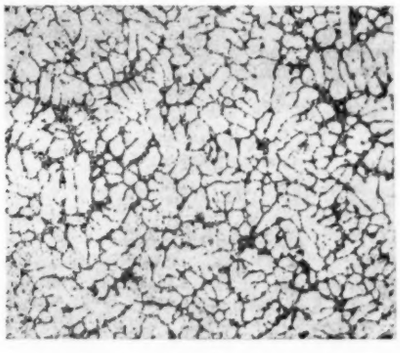


FIG. 13.—ALPAX-GAMMA WITH 6 PER CENT. SI AND 0.4 PER CENT. TI. × 40.

being shown by a comparison with an Al-Si alloy free from Mg and one with 0.5 per cent. Mg in different stages of the heat-treatment (Fig. 15). The static properties attain their substantial increase by age-hardening at 150 deg. C. The fatigue strength is not affected, but attains its increase by the homogenisation heating. The Si solubility must therefore be held responsible for the change in the fatigue strength. As will be gathered from Fig. 16, the fatigue strength is also influenced much more than the static properties by the particular Si content in solution, according to a given thermal temperature.

Starting from a corrosion resistant alloy type with small additions of Mg and Si, in which the amount of the compound Mg_2Si was less than the maximum solubility of 1.85 per cent., the Si content was increased to about 4 per cent. for the purpose of improving the casting properties, particularly for chill castings, the Mg content being increased to about 3 per cent., so that the total content of Mg_2Si was about 4.5 per cent. Further additions are Mn and Ti. This alloy is known in Germany by the name "KSS 250," and heat-treatment imparts to it excellent mechanical properties. With chill-cast

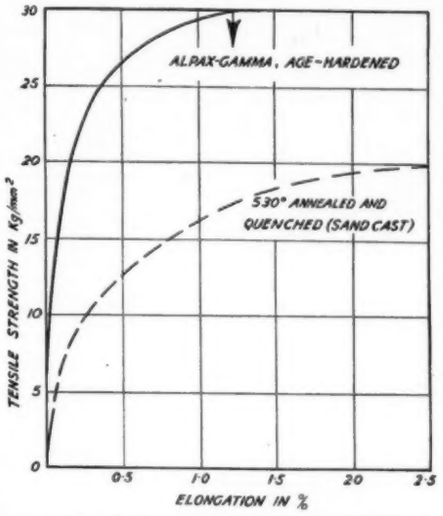


FIG. 14.—INCREASE IN TENSILE STRENGTH OF QUENCHED ALPAX WITH 0.4 TO 0.5 PER CENT. MG BY HEATING FOR 20 HRS. AT 150 DEG. C.

bars, a tensile strength of 10.3 tons per sq. in., an elongation of 1.6 per cent. and a hardness of 69 kg./mm.² was obtained in the metal as cast. After a heat-treatment consisting of annealing at 540 deg. C. for 3 hrs. and age-hardening at 140 deg. C. for 20 hrs., a tensile strength of 21 tons per sq. in., an elongation of 1.3 per cent., and a hardness of 124 kg./mm.² was obtained).*

Attempts to render alloys having an excess of Mg heat-treatable by additions of Ce, Z and Mn have met with success, especially in the case

FIG. 15.—FATIGUE STRENGTH OF ALPAX WITH 0 AND 0.5 PER CENT. MG IN DIFFERENT CONDITIONS.

of rapid solidification, when the Mg_2Si is obtained in a finely divided state, thus facilitating the diffusion during the artificial age-hardening treatment.[16] The optimum composition is 3 per cent. Mg; 0.8 per cent. Si; 0.3 per cent. Ce; 0.8 per cent. Zn; and 0.8 per cent. Mn. By a heat-treatment consisting of homogenisation at 600 deg. C. for 6 hours followed by age-hardening for 16 hours at 170 deg. C., a yield point of about 15.8 tons per sq. in. and a tensile strength of 17.1 tons per sq. in. for an elongation of about 2.5 per cent. are attained The corresponding values in the as-cast state are 7.0 tons per sq. in., 10.7 tons per sq. in. and 3 per cent.

* The author is indebted to Dr. Sterner-Rainer for these data.

Age-Hardening by $MgZn_2$

Finally, reference may be made to another group of alloys which were not found serviceable as rolled alloys on account of a tendency to stress-corrosion but which afford certain advantages as cast alloys and have begun to be used on an increasing scale. These are the alloys known by the name "G 54," the hardening constituent of which is the compound $MgZn_2$ and to which Mg and Zn are added either in the proportions corresponding to the compound or with an excess of Mg or Zn.[17] The optimum alloys are those with a Mg-Zn ratio between 1:3 and 1:5.4, with which it is possible, after heat-treatment (annealing at 475 deg. C., quenching and age-hardening at 150 deg. C. for 14 hours) to attain tensile strengths of over 25 tons per sq. in. and hardnesses of over 140 kg./mm.², but with only a slight elongation. In this case, the total content of Mg + Zn lies at 9 per cent. A smaller addition, for instance

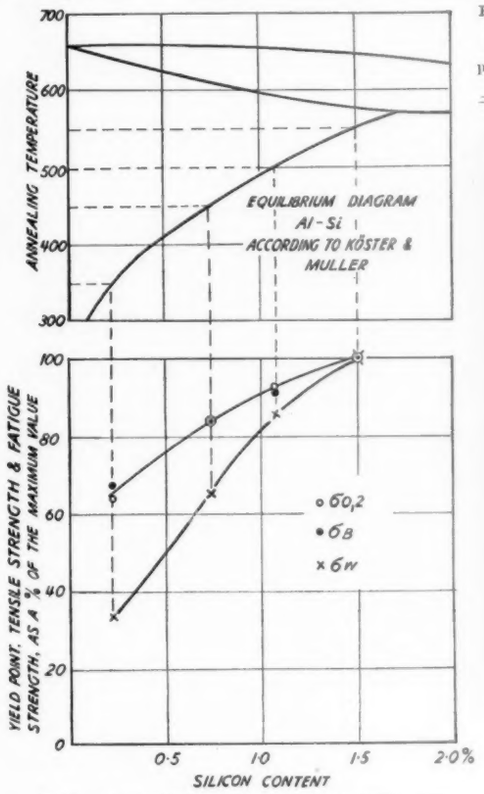


FIG. 16.—VARIATION OF THE STATIC AND DYNAMIC PROPERTIES OF ALPAX WITH THE SI SOLUBILITY.

7 per cent. Mg + Zn, results in tensile strengths of 22.2 tons per sq. in. and hardnesses of 130 kg./mm.² with an elongation of 3 to 4 per cent.[18] The particular significance of these alloys, however, is that they are very suitable for treatment by anodic oxidation, a very uniform and attractive surface being produced. The alloy is therefore greatly in demand for purposes where a good appearance and good mechanical properties are required

Summary

Various problems relating to foundry practice and metallurgy recently studied in Germany are discussed. The removal of gases from the melt is best effected by a combination of salt treatment and standing in a neutral atmosphere. Absorption of gases from the mould can be reduced by lowering the pouring temperature, shortening the period of flow and increasing the rate of cooling.

The influence of Ti on the fatigue strength of Alpax with various Si contents is discussed, as is also the influence of various heat-treatments. In the case of this and certain other alloys, the increased solubility of Mg_2Si at high temperatures is utilised for improving the mechanical properties by heat-treatment.

The same property is also possessed by the compound $MgZn_2$ contained in the artificially age-hardenable alloys of the "G54" group, distinguished for their excellent suitability for anodic oxidation.

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MR. J. E. NEWSON

(Author of the Bradford Conference Paper printed on the facing page).

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batch should differ so much from the chrome concentrate batch and the calcined Grecian chrome batch is not clear, unless the barium sulphate has reacted with the impurities in the two latter batches to produce a more refractory bond—perhaps through being subjected to high-temperature calcination.

In most cases the lowest porosity and the highest bulk-density figures were obtained on test-pieces made by the hand-tamping process, as used for the manufacture of basic and neutral refractories. It is noteworthy that the range of best grading compositions from the point of view of low porosity and high bulk density comprises the 45 per cent. coarse, 10 per cent. medium, and 45 per cent. fines composition, as specified by previous investigators when working on entirely different materials, namely, silica and magnesite.

The slag-test crucibles prepared from the grading compositions giving the lowest porosity and highest bulk-density values were found to offer the greatest resistance to slag absorption, whereas those having high porosities had absorbed the slag and had eventually lost their shape by bloating. The sound briquettes have been subjected to a simple spalling test. This test, with the application of a slight tensional force after test, indicates that, although the briquettes prepared from the more coarse grading compositions offer very good resistance to spalling, they become weak structurally and are also exceptionally friable.

Chrome Ores in Refractories

Report Submitted to Ceramic Society

At the Spring Meeting of the Refractory Materials Section, held last month at the Imperial Hotel, Torquay, a report on "Chrome Ores as Used in the Refractories Industry" was presented. In it, mention was made of the possibility of calculating the amount of fairly pure powdered magnesite necessary to be added to a chrome batch to convert the serpentine (present in the chrome material) into forsterite, a more refractory magnesium silicate than serpentine. Theoretically, 0.33 per cent. magnesia would be needed for each 1 per cent. silica in the ore, and it was thought such small additions would not materially affect the neutral properties of the bricks. In the experimental work other proportions were also used, and other investigations were undertaken for producing a neutral chrome brick to withstand the "cutting-in" action exerted by the silica bricks above them, as well as to resist high pressures at high temperatures, by adding basic and neutral bonds respectively (in the form of lime and barium sulphate). The effect of the grading of a high-grade chrome concentrate on the physical characteristics of the fired product was also closely studied.

For ascertaining the effect of small proportions of magnesia to a chrome batch, a Rhodesian chrome ore was used, and in some mixtures a dead-burned Grecian magnesite instead of pure calcined magnesia. The dried test-pieces (briquettes) were fired at 1,580 deg. C. (one set at 1,500 deg. C.) in a gas-fired furnace, measurements being made for average wet-to-fired linear contractions, and refractoriness-under-load tests (at 1,580 deg. C., with a load of 50 lbs. per sq. in.). The results indicated that addition of the calculated theoretical quantity of magnesia produced no marked improvement in the mechanical strength at high temperatures, except in the case of the test-pieces in which Grecian magnesite had been added, this more favourable result being probably due to the small proportions of ferruginous impurities (in the Grecian magnesite), promoting reaction with the serpentine. Microscopic examination gave similar indications, the forsterite produced revealing itself as doubly refractive crystalline particles. Further confirmation was found in the higher refractoriness-under-load tests where the production of forsterite has been ascertained.

Lime Bonding.—To give the necessary proportion on firing, lime was added as calcium carbonate. Results of tests indicate that a product made from a lime-bonded chrome concentrate batch shows no marked improvement in mechanical strength at high temperatures over that of the batch alone, and that a lime-bonded Rhodesian chrome batch has an even lower mechanical strength at high temperatures than one made from Rhodesian ore alone.

Barium Sulphate Bonding.—Results obtained indicate that barium sulphate provides efficient bonding power at high temperatures under pressure. Thus in the final fail-point temperature of the barium-sulphate bonded chrome concentrate test-pieces over that of the chrome concentrate batch alone is particularly noticeable. The comparatively low start-to-fail points observed is probably due to high porosity which, under works conditions, would be considerably reduced by correct grading and high making pressures.

Further experiments with barium sulphate as a bond were made with a high-grade Turkish chrome ore and a normal grade Grecian ore. Three different combinations of grain size were used in grading them. From results of refractoriness-under-load tests, the best grading for the calcined Turkish ore seems to be 10 per cent. medium grains, and 45 per cent. each of coarser and finer grains, each of the three groups covering a specified range of grain size. No apparent advantage was gained by the use of barium sulphate as a bond.

With the calcined Grecian ore, the effect of adding 5 per cent. barium sulphate was very noticeable for all three grading compositions, the best results being shown by the third grading composition (22 per cent. coarse, 38 per cent. fine, with 24 and 16 per cent. respectively for two intermediate ranges, the second grading being 7 per cent. coarse, 8 per cent. fine, with 50 per cent. and 35 per cent. of intermediate ranges). Why the calcined Turkish chrome

(Continued in previous column.)

Some Physical Factors in Casting High-Strength Brasses*

By J. E. NEWSON, M.Met.†

In the third Edward Williams Lecture,[1] delivered in June last to this Institute by the author's former Professor, Dr. C. H. Desch, some of the most important physical factors in the casting of metals were discussed. In view of the very high standard of that address, it is with no little trepidation that the task has been undertaken in this Paper to consider some of the less important factors to which he then referred, with special mention of those which are of interest in the casting of high-strength brasses. These alloys have been chosen since they illustrate these factors very well, and because they are used for some of the largest non-ferrous castings in production. In such large castings the relative importance of these factors increases, and better facilities for studying them become available. They are, of course, of quite considerable significance for all non-ferrous castings, the degree varying with the mass of the casting and certain inherent properties of the alloys. These alloys possess many desirable mechanical and physical properties, but present certain difficulties to those foundrymen who have had little experience of them.

The mechanical properties of most alloys are influenced by the grain size, and the form and distribution of the constituents. In practice, the ideal of a uniform grain size is almost impossible of achievement, but a careful study of conditions and a recognition of the principles involved can be of some help in approaching the ideal. The grain size is controlled largely by the thermal conditions which prevail from the time the molten metal enters the mould until the cold solid casting is knocked out. It is important to remember that not only the total quantity of heat to be dissipated must be considered, but also the rate at which it is dissipated.

The thermal conditions can be divided under two heads:—(1) Those which are due to specific properties of the alloy itself and can only be varied by change of composition. These include the specific heat, the latent heat of fusion, the thermal conductivity, the temperature and extent of the freezing range. (2) Those which can be varied under control by external means, such as the casting temperature and degree of superheat of the metal, and the nature and properties of the mould material.

Factors for Control

It will be realised that some measure of control is possible and can be exercised to advantage, especially with large castings, by the foundryman who is prepared to consider this aspect of his craft. The alloy to be used, the mass of the casting, its sections and general design, and the ratio of cooling surface to volume are chosen by the designer, but these form the basis on which the casting temperature must be selected. The casting temperature, in conjunction with the specific heat and latent heat of fusion, establishes the total heat content of the molten metal poured into the mould.

The rate at which this heat is given up by the metal is dependent upon the initial temperature difference between the metal and the mould, the thermal conductivities of metal and mould, the properties of the surfaces of metal and the mould, and again the volume-area ratio.

In the past there has been a marked tendency to regard such properties as specific heat and latent heat as of academic rather than practical interest and importance. This is not surprising, as even to-day there is available very little published information except in the case of pure metals. It must be admitted that they are of real significance from two practical standpoints.

In the first case, the cost of melting alloys is directly related to the amount of fuel, be it coke, coal, oil or electricity, consumed to provide the necessary heat units to raise the alloy to the casting temperature and the number of heat units varies with the specific heat, latent heat and casting temperature. An opportunity arose of obtaining a direct example of this on a 650-lb. oil-fired tilting furnace, where a study of the oil consumption showed that almost exactly the same quantity of oil was consumed to melt 200 lbs. of aluminium alloy, casting at 650 deg. C., as to melt 650 lbs. of Admiralty gunmetal casting at 1,150 deg. C. Secondly, it must be remembered that when specific heat, latent heat and casting temperature are high, the total heat content to be dissipated is proportionately high, and will have an important influence on grain size and mechanical properties.

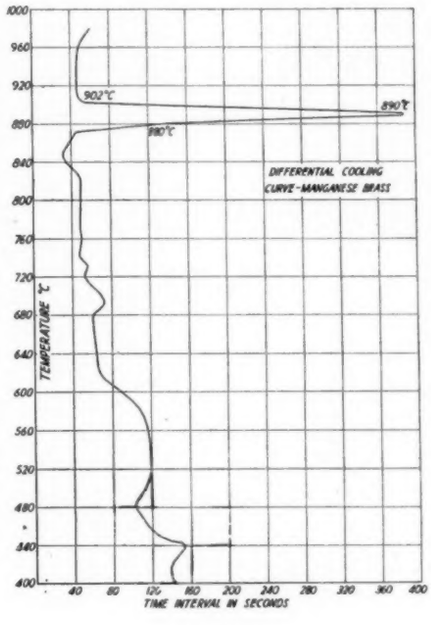


FIG. 1.

It would perhaps be as well at this stage to consider these several factors individually and then to examine their collective effect in the case of the alloys under review.

Specific Heat

This is usually expressed in metric units, and is the quantity of heat required to raise 1 gm. of the material through 1 deg. C. = calories per gram. per deg. C. The specific heat is not constant over all temperatures, and in general increases with rising temperature until the metal is molten, when a steady value is obtained. The specific heats of a number of metals of high purity have been determined at the N.P.L., and Table I is abstracted from their "Physical Constants of Pure Metals."[2]

These figures are quoted to show how the values vary for the different metals. The determinations in the case of alloys are much more difficult, being complicated by phase and allotropic changes during heating and cooling. In a recent Paper by Sykes and Wilkinson,[3] who were studying the atomic re-arrangements in brasses consisting wholly or in part of the β-constituent, the specific heats of these very pure copper-zinc alloys were published, covering a range of temperatures. A study of this Paper reveals the difficulties associated with precision measurements of this property of alloys, and it can readily be appreciated why so few data are known for the more complex alloy systems. Their "specific heat-temperature" curves show values of 0.094 cals./gm./1 deg. C. at 100 deg. C., reaching 0.104 cals./gm./1 deg. C. at 240 deg. C., rising sharply to a maximum of 0.27 cals./gm./1 deg. C. at the critical temperature of about 450 deg. C., falling away again to the previous curve. The high-strength brasses exhibit a break in the cooling curve at this critical temperature which will be referred to at a later stage.

TABLE I.—*Specific Heats of Common Non-Ferrous Metals.*

Metal.	Melting point. Deg. C.	Specific heat. Cals. per gm. per 1 deg. C.	
		At 100 deg. C.	Molten.
Aluminium ..	657	0.228	0.36
Copper ..	1,083	0.097	0.122
Lead	327	0.028	0.020
Tin	232	0.064	0.056
Zinc	420	0.095	0.124

Latent Heat of Fusion

The latent heat of fusion is the number of gram. calories required to convert 1 grm. of the material from the solid to the liquid state without change of temperature. Table II from the same N.P.L. Tables of Physical Constants[2] shows the values obtained for the same pure metals, but it should be noted that the value assigned to aluminium is still not finally settled. Here again the figures relate to very pure metals, and attention is drawn to the widely different values for the several metals.

TABLE II.—*Latent Heat of Fusion of Some Common Non-Ferrous Metals.*

Metal.	Melting point. Deg. C.	Latent heat of fusion. Gm. cals. per gm.
Aluminium	657	92.4
Copper	1,083	49.95
Lead	327	6.26
Tin	232	14.6
Zinc	420	26.6

It is very difficult to find reliable values for alloys, due perhaps in part to complications arising from heat of formation of compounds, but a new cooling curve method is being tried out at the N.P.L.

Thermal Conductivity

The thermal conductivity (K) is a measure of the heat transference, and is usually given as the number of gram.-calories which pass per second through one cubic centimetre of the substance when the temperatures of the opposite sides of the cube are maintained at a difference of 1 deg. C. The values generally decrease slightly with rising temperature, and average values are aluminium 0.50, copper 0.88, lead 0.075, tin 0.13 and zinc 0.26. This property is of some importance in large castings by affecting the time taken for temperature gradients to disappear and uniform cooling conditions to become established, thus affecting the initial grain size of the casting.

Freezing Range

A pure metal melts and freezes at a constant temperature, but in most alloys the process extends over a range of temperature, and at this

* One of the Papers in the Symposium on Non-Ferrous Subjects held by the Institute of British Foundrymen at the Thirty-fifth Annual Conference, which is taking place in Bradford this week.

† Manganese Bronze and Brass Company, Limited.

stage both solid and liquid are present, giving rise to a pasty condition, which can be a serious hindrance to the effective feeding of a casting. As an alloy cools in the molten condition, it contracts with falling temperature. At the change from the liquid to the solid state there is (with only one or two exceptions) a marked shrinkage in volume, followed by a further steady contraction to normal temperatures. This phenomenon is well known to foundrymen, and is provided for by making patterns to the contraction rule, and by the judicious use of risers and feeding heads in the mould. The contraction allowance for high-strength brasses varies from $\frac{5}{32}$ in. to $\frac{7}{16}$ in. to the foot, and generous risers must be provided. Fig. 1 shows a typical cooling curve for an alloy of this type, and in view of the behaviour of the alloy in the risers of a large casting, the actual temperature interval of the freezing range is surprisingly short. On the other hand, the time interval is long, and the importance of this will be referred to when considering all the factors together.

Casting Temperature

This is the factor which lends itself most readily to control. It may be stated as a generalisation that in many non-ferrous metals slight variations of casting temperature have a more marked influence on the mechanical properties than quite appreciable variations in the proportions of the major constituents. This is particularly true of the gunmetal and tin bronzes, and to a less marked degree with the high-strength brasses. The choice of the appropriate casting temperature is frequently a matter of judgment and experience of the alloy. A useful basis is 10 per cent. superheat, that is, for an alloy melting at 1,000 deg. C. a basis would be 1,000 + (10 per cent. of 1,000) = 1,100 deg. C. For castings of thin sections and large surface a further addition would be necessary, and for large compact castings a reduction could be made.

A number of types of base-metal thermocouples and indicators, sufficiently robust for foundry use with reasonable care, are obtainable, and it is advisable to use a pyrometer to obtain consistently good results. Lighting conditions in most foundries are not ideal, and subject to considerable variation throughout one day, as well as from day to day, and, in addition, the oxide films present on the different kinds of metal make the estimation of temperature by colour very deceptive, and optical pyrometers unreliable.

Mould Material

The thermal properties of mould materials have not received much attention in the past, although the use of metallic inserts into the mould, known as chills or denseners, is a common practice to accelerate the rate of cooling of heavy sections. Hudson[4] has carried out some interesting practical work on this subject, and in a recent article suggested the use of non-metallic materials of high thermal conductivity. In the course of his investigation he noted that most of the commonly used foundry sands, whether green or dry, had practically the same low thermal conductivity, but that graphite or silicon-carbide mixtures could be prepared, with suitable moulding characteristics, and thermal conductivities between that of mild steel and copper. He also noted the low thermal conductivity of ordinary foundry blacking, which compares unfavourably with a graphite base wash. The specific heat of the moulding material has a slight influence on the rate of cooling of a casting, but becomes insignificant in the case of sands of such low conductivity. The thermal conductivity (K) for sand is 0.00013, for Acheson graphite 0.300, whilst the specific heats are: sand 0.19 and graphite 0.467.

Effect of Fundamental Physical Factors

It is proposed to consider now in general terms the collective effect of these factors in the primary crystallisation of the high-strength brasses cast in sand. It is impossible to observe all that occurs in a mould during casting, but by studying a large number of partly-open moulds, one can visualise the flow of the metal and speculate as to the conditions existing in the mould. When a stream of high-strength brass enters a well-designed gate and passes thence to the mould quietly, a thin tenacious film of aluminium oxide appears on the surface of the metal. This film breaks and is continuously reformed, and to some extent serves as a protection to the metal. On the other hand, if the metal enters through a wrongly designed gate, and the stream of metal breaks into turbulent flow, zinc oxide or dross is formed and carried along by the stream, lodging against the walls or in recesses or angles of the mould to appear as defects in the casting. When the casting is stripped it should show a smooth surface of golden yellow colour, which is the natural colour of the alloy seen through a very thin transparent film of aluminium oxide. Very small percentages of aluminium are sufficient to produce this effect, whilst high percentages of manganese give a red or purple iridescent tinge to the film.

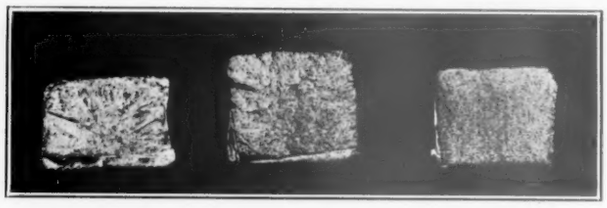
If now the thermal changes which occur be considered, it is obvious that heat is given up by the metal to the mould surface. The temperature of the mould face is raised and that of the metal lowered until a uniform temperature is reached where they meet. On account of the very low thermal conductivity of the sand only a very thin layer of the mould reaches the temperature of the metal, and a steep temperature gradient is established. In the metal, a certain number of heat units are lost to the sand, and, dependent upon the specific heat and the latent heat of fusion, a fall in temperature results; with normal casting temperatures this fall in temperature is sufficient to lead to the formation of a shell of solid metal.

The conductivity of the metal is high, and heat flow is further assisted by convection currents and movement of the liquid metal, and any temperature gradients will be slight. This rapid distribution of heat tends to equalisation of temperature, with the result that the temperature of the molten metal quickly falls to that at which it is in equilibrium with the solid metal formed. Hensel,[5] in a recent Paper on the primary crystallisation of metals, states that the degree of superheat regulates the thickness of the shell of solid metal—the lower the superheat the thicker the shell—and the temperature of the melt drops almost immediately to the temperature of solidification. "When casting a superheated melt into a hot sand mould, crystallisation started in this case only after the entire mass had cooled down to the melting point. The casting temperature affects greatly the time of solidification and therewith the velocity of crystallisation." He also stresses the importance of the latent heat of fusion and considers that the rate at which this can be dissipated largely controls the velocity of crystallisation.

The author had found previously by pyrometers placed in the heads of propellers up to 15 tons cast weight poured at 970 deg. C. that the temperature fell almost immediately to 890 deg. C., the temperature at which freezing began. Solidification was complete at 870 deg. C., an interval of only 20 deg., but the time to pass through this range is some hours, after which the rate of cooling is more normal. This freezing range is easily confirmed in the laboratory, where the time interval is again strikingly shown.

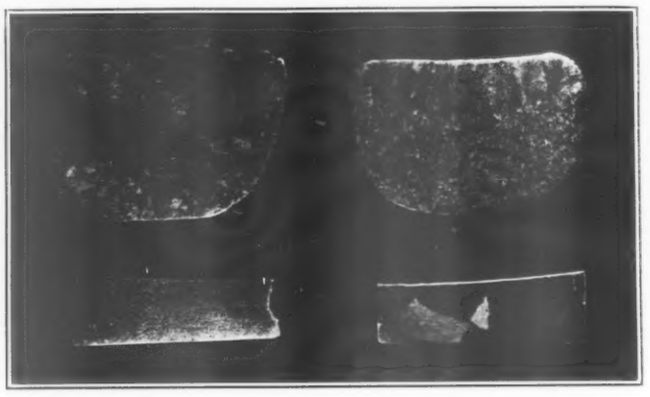
During the freezing, when liquid and solid phases are present together, the metal is in a pasty state, which accounts for some of the difficulties of feeding castings in these alloys. Such a slow rate of cooling through the freezing range tends normally to produce in alloys a coarse primary grain size. The grain size, however, is also affected by the number of nuclei which may be present. These alloys contain iron in amounts up to 1.5 per cent. and the action of the iron in refining the structure is important and interesting.

Bauer and Hansen[6] studied the effect of small iron additions to the copper-zinc system. They found that with an iron addition of about 1 per cent., a primary precipitation of an iron-rich copper-zinc compound occurred at about 905 deg. C.—a few degrees above the liquidus of the copper-zinc system. A few degrees lower a peritectic reaction occurs between part of this and the liquid melt. With an iron content below the critical value, all the primary compound was absorbed in the reaction; the compound entering into the reaction is precipitated later as a secon-



A B C

FIG. 2.—FRACTURES OF FINGER TEST-BARS: A, 0.68 PER CENT. Fe; B, 0.73 PER CENT. Fe; C, 1.0 PER CENT. Fe.



D C

A B

FIG. 3.—A, FINGER BAR AS CAST; B, FINGER BAR ANNEALED AT 700 DEG. C. FOR 1 HR.; C, NORMAL ALLOY, COOLED, REHEATED ABOVE PHASE CHANGE; D, LOW-IRON ALLOY, COOLED, REHEATED ABOVE PHASE CHANGE.

dary form. When there is sufficient iron present for the primary to persist, it serves as nuclei for crystallisation of the metal. When it is absent, and the secondary form appears after the copper-zinc system has crystallised, the nuclei are not available. This appears to be the explanation of the striking differences observed in the fractures of test-bars taken from melts of high-strength brass when the iron is below normal.

For these alloys the critical iron content appears to be about 0.75 per cent. Fig. 2 shows the fracture of finger test-bars, containing 0.68 per cent. Fe, 0.73 per cent. Fe and the more normal 1 per cent. Fe. The first shows what is known in the works as a "fibrous fracture," and the columnar crystals at right angles to face of mould persist across the section and meet. In the second, columnar crystals extend only partly across the section, and there is then a zone of equi-axed crystals. In the third case, only equi-axed crystals of very small size are to be seen and there are no columnar crystals. This type of columnar primary crystallisation has been observed on small chill bars, chill-cast extrusion ingots and sand castings when the iron content has been too low to provide the nuclei which lead to refinement of grain size. Some writers have referred to this iron-rich compound (also called the blue-etching constituent) as "excess hardener," but with normal compositions it is not so much an "excess" as a necessity, to obtain the desired structure. Recent work suggests that some other additions to high-strength brasses may through similar reactions act as refining agents.

So much for the primary crystallisation of the high-strength brasses. On very large castings, combination of circumstances may in special instances lead to a phenomenon which modifies this primary structure. When the alloy changes from the liquid to the solid state it appears first as the β-solid solution. With further cooling there is a phase change and the α-solid solution is precipitated. During recent years much work has been carried out on recrystallisation and grain growth which occur on annealing cold-worked metals. Thanks to the classical researches of Carpenter[7] and Elam, this is now one of the most widely used methods of producing single crystal test-pieces. Various authorities[8, 10] also state that recrystallisation and grain growth can occur in alloys by reheating above a phase change-point, but it is difficult to trace any record of such examples having been examined. Logan[11] records an example in propeller brass. One characteristic which distinguishes this grain growth from coarse grains due to slow primary crystallisation is that in the first case large grains appear adjacent to very fine grains without intermediate sizes, whilst in the second case there may be a regular graduation of sizes.

Phase Changes

The phase change, necessary for grain growth, is due, in the high-strength brasses, to the re-solution of the α-solid solution in the β-solid solution. The temperature of this change varies with the composition and is indicated on the thermal equilibrium diagram by the line separating the β from the $\alpha + \beta$ fields.

Thermal History of Large Castings

In a very large casting one can imagine how the conditions for recrystallisation and grain growth can arise. Immediately after casting, one has a mould in which is a shell of solid metal containing liquid metal. The face of the mould has been heated and the solid shell cooled until a uniform temperature is attained for a short time at the interface. The temperature of the metal in some areas may be depressed not only below the freezing point, but to the point at which the α-phase just begins to separate. But within the shell is metal which is still liquid, and is at a higher temperature, and this is a condition of unstable equilibrium. By convection and conduction heat is transferred from the hotter to the cooler metal (and it must not be forgotten that the latent heat of fusion is also liberated), and this may raise the temperature of the cooled metal above the phase change point again. The temperature gradient in the metal now becomes very slight, and once the whole mass is solid, transfer of heat is by conduction only, and thus the second cooling down to the phase change temperature may be very slow. To verify these assumptions some experiments were carried out.

Experimental Evidence

(1) Chill-cast "finger" test-bars, about $\frac{1}{2}$ sq. in. cross-section, in which the rapid cooling restricts the separation of the α-constituent, were re-heated at 700 deg. C. for 1 hr., and recrystallisation and grain growth occurred so that the polished and etched specimen showed that the cross-section consisted of only 4 or 5 grains, *vide* Fig. 3 (A and B).

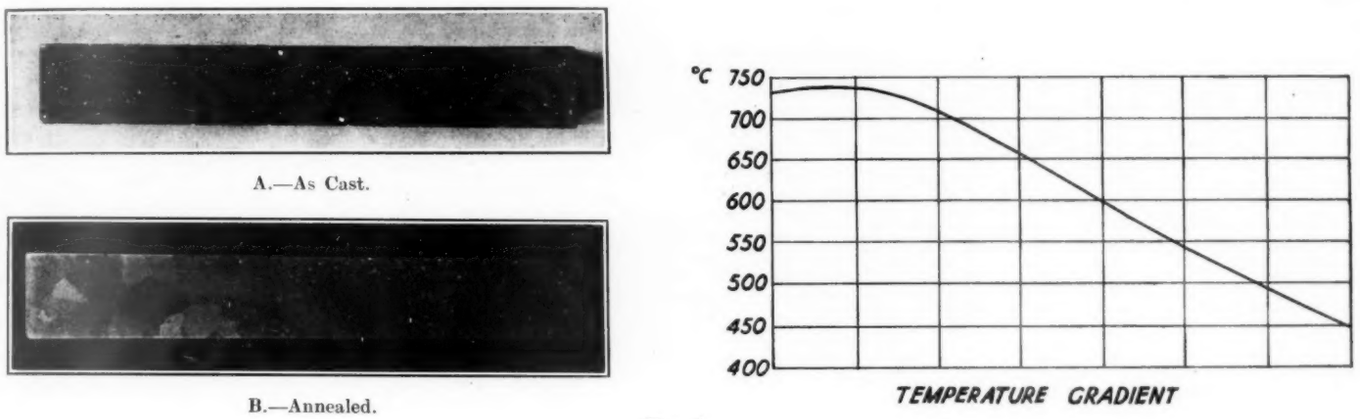
As the chill-cast bar may have been in a state of internal stress,[9] due to the rapid cooling, another experiment was made, which also served to illustrate the refining influence of iron.

(2) A small crucible containing 650 gms. of the normal alloy was heated in a vertical electric furnace and raised to a temperature of 980 deg. C., 90 deg. C. above the melting point of the alloy. The current was switched off, and the temperature fell until the phase-change temperature was approached, when the doors of the furnace were opened and the upper part of the crucible cooled more rapidly than the base. The doors were then closed, current switched on again and the temperature raised above the phase-change temperature, maintained for 1 hr. and then the temperature was lowered slowly (about 5 deg. C per minute). When cold the metal was removed from the crucible, sectioned, polished and etched, and it was found that recrystallisation had occurred in the region which had cooled below the phase change temperature and then been re-heated. The line of demarcation of large and fine grains was well defined, as seen in Fig. 3 (C).

The experiment was repeated under identical conditions as to the weight of melt, heating and cooling conditions with an alloy containing 0.70 per cent. iron instead of the 1 per cent. in the previous case. It was then found that the recrystallised area was larger in extent and the small grains were coarser than in the first case (see Fig. 3 (D)).

The presence of the blue-etching constituent would therefore appear to inhibit grain growth, and this restriction by a separate phase under certain conditions has been noted in the case of recrystallisation following cold-work. In the above experiment, in which the metal was not cast, the possibility of stress being present in the pieces seems very remote, and the recrystallisation and grain growth are shown to occur purely as a result of the cooling and reheating.

(3) A portion of a sand-cast test-bar was cut, 1 in. by 1 in. by 7 in. long, and one face was polished, etched and photographed. The grain was uniform, as is shown in Fig. 4 (A). The bar was annealed for 1 hr. at 600 deg. C. to ensure freedom from stress, and was then heated in an electric furnace, so that one end was raised to 750 deg. C. and the other end projected from the furnace and reached 445 deg. C. A temperature gradient was thus established, and this was measured by a pyrometer inserted into holes drilled at 1 in. intervals along the bar. The temperature conditions were maintained for 4 hrs. to ensure that the phase-change would be completed at the hotter end of the bar, and after cooling in air the face was again polished and etched, with the result shown in Fig. 4 (B).



A.—As Cast.

B.—Annealed.

FIG. 4.

It should be noted particularly that, although the temperature varied evenly along the bar, the very striking change in grain is remarkably abrupt with no intermediate sizes, indicating that it has occurred only where the critical conditions have been fulfilled. Fortunately, the combination of these critical conditions occurs only rarely in practice, and now they are recognised, two methods of approach to the problem of eliminating them suggest themselves, namely, to avoid the initial fall of temperature below the phase change or to modify the alloy or mould material so that reheating above the phase change is not likely to occur.

The subsequent cooling of the casting leads normally to precipitation of the α-solid solution, the rate of cooling affecting the size and distribution. There is just one further point to be mentioned. When a large casting shrinks on cooling, it seems very probable that the casting "sits down" on the lower part of the mould and shrinks away from the upper part. It is difficult to determine what will be the effect on the rate of cooling of the heated air space between the casting and the mould, particularly when it is remembered that the surface of the

(*Concluded on page* 484.)

Protective Coatings other than Paint

Extracts from a Paper on "Protection of Steel by Coatings other than Paint," by H. Sutton and C. O. Braithwaite, published in the Fifth Report of the Corrosion Committee (Iron and Steel Institute Special Report, No. 21)

This Paper is based on experience gained over a number of years from tests of steel samples treated by protective processes.

The corrosion tests employed were (*a*) the intermittent sea-water spray test, in which the samples were placed in an open-sided shed and sprayed three times each working day with sea-water taken from the English Channel, and (*b*) a beach exposure test carried out at Felixstowe, where the samples were fixed midway between high- and low-tide levels. In a few instances samples were also exposed to the influence of contact with tropical waters at Singapore.

In general, the results of the intermittent sea-water spray tests or of marine exposure tests showed that the coatings which afforded the best protection against corrosion were as follow:—(*a*) Coatings of electrodeposited zinc or cadmium; (*b*) coatings of not less than 0.0015 in. of electro-deposited nickel; (*c*) coatings of aluminium or zinc applied by metal spraying; (*d*) coatings of zinc applied by the Sherardising process; (*e*) coatings of aluminium-applied by dipping. Most of the samples, when protected by any of these methods, showed little or no rust after one year's exposure to the above corrosion tests. Coatings of chromate-pigmented lanolin gave very good results in atmospheric exposure tests and sea-water spray tests.

The following coatings afforded moderate protection:—(*a*) Coatings of not less than 0.0005 in. of electrodeposited chromium; (*b*) coatings of nickel rolled on; (*c*) coatings of phosphates supplemented by the application of paints.

Poor protection against corrosion by sea water was afforded by:—(*a*) Thin coatings of electro-deposited chromium applied over electrodeposited coatings of certain other metals; (*b*) coatings of aluminium applied by the calorising process; (*c*) coatings of zinc applied by the hot-galvanising process and thinned down by drawing operations; (*d*) coatings of phosphates; (*e*) coatings of unpigmented temporary rust preventive to specification D.T.D.121B.; (*f*) coatings applied by the "gun-blacking" process.

In cases where the protective coating was supplemented by varnish or enamel, increased protection was generally obtained. In certain instances, however, the subsequent application of organic coatings was detrimental.

Appended are the authors' general remarks and discussion of results.

Electro-Deposited Coatings

Electro-deposited coatings are capable of easy application to small pieces, but cannot conveniently be applied to large structures. An important feature of electro-deposition processes is the manner in which the thickness of the coatings can be controlled. Wires, strips, etc., can be treated in continuous plant, and large quantities can be dealt with on a commercial scale. A high degree of protection against corrosion is obtainable by plating with zinc or cadmium. In marine atmospheres there seems little to choose between these metals when considered from the point of view of the protective qualities of electro-deposited coatings. Zinc is very much cheaper than cadmium. On the other hand, cadmium-plating is probably more easily operated and controlled on a commercial scale than zinc-plating. It is also usual to deposit cadmium more rapidly than zinc. The electro-deposition of coatings of uniform thickness on articles of very irregular shape is a matter requiring special arrangements and is usually somewhat costly, except in special cases where a special apparatus suitably designed can be utilised for plating a large number of similar pieces. Whilst the scope of application of electro-deposited coatings in the protection of engineering structures against corrosion is somewhat restricted, the results obtained suggest that, in relation to the amount of metal present in the coating, the degree of protection attained is exceedingly high in the case of zinc and cadmium deposits on steel. Springs are embrittled by normal pickling and plating operations, but may be pickled and plated without appreciable embrittlement by the use of appropriate methods.

Metal-Spraying Processes

There appears to be considerable scope for the application of the metal-spraying process to engineering structures, since it can be applied to manufactured or assembled pieces without difficulty. Thorough cleaning of the surface by shot- or grit-blasting appears to be essential prior to the metal-spraying itself. The actual spraying is a straightforward operation so far as coatings of aluminium, zinc and other easily fusible metals are concerned. Little work appears to have been done on sprayed coatings of alloys, such as cadmium-zinc for the protection of steel against corrosion, and this would appear to be a very promising field for research.

An important feature of the metal-spraying process is that it is, for practical purposes, an engineering process. As the pieces are not heated appreciably while being sprayed, the physical and mechanical properties are not affected. Embrittlement, such as may result from pickling and plating operations on the harder steels in particular, does not arise, nor is there any tempering or softening effect such as normally results from the hot-galvanising or calorising of any other than soft steels. Sprayed metal coatings can be applied to steel in contact with other metals, and can also be applied to soldered or welded-steel joints.

Sprayed coatings appear to form a good basis for the application of paints, though information on the best paints for use as supplementary protectives appears to be needed, a situation which also exists in relation to other metallic coatings.

Tests of samples sprayed by a method employing metal powder have recently been investigated. It appears that the sprayed coatings so produced are of more open texture and more friable than coatings produced by the wire-spraying process as operated in the United Kingdom.

All the sprayed coatings examined to date in the as-sprayed condition appear to be unsuitable for application to pieces which are to be worked subsequently by processes involving deformation, *e.g.*, pressing, stamping or drawing.

Sherardising and Calorising

Sherardising and calorising necessitate the packing of the cleaned pieces in boxes or drums for treatment. These processes are quite conveniently applied to pieces of moderate size, but special plant is required for the treatment of large pieces. Normally the processes are not applied to large units. In Sherardising, the strength properties of high-strength and hard steels such as spring steels are affected by the treatment, but, when required, the treatment can be operated in lower temperature ranges than those normally used and the tempering effect of the thermal treatment is reduced substantially. Sherardising, effected under appropriate conditions, affords excellent protection to steel, and, from the point of view of the weight of zinc present, the coatings are of the same order of efficiency as electro-deposits.

Aluminium-dipping is a process for which there would appear to be a considerable future, though the commercial operation of such a treatment of steel parts has not yet, to the authors' knowledge, attained an important position. Thorough descaling of the steel is essential, and a light electrodeposit of zinc or cadmium applied to the surface has proved of advantage in securing a uniform "wetting" of the surface with aluminium when the pieces are dipped. It appears possible, however, that, with the use of a suitable flux in dipping, the preliminary coating of zinc or cadmium could be dispensed with. Provided that the coatings cover the steel satisfactorily, they afford a very high degree of protection against corrosion at normal and elevated temperatures. The coatings adhere very firmly to the steel base, and treated pieces can be worked subsequently by bending, pressing, drawing, etc. Appreciable softening of medium-strength and hard steels may be expected to result from the dipping treatment.

The scope and usefulness of hot-galvanising are already well known. The temperature at which hot-galvanising is carried out is sufficiently high to soften hard steels appreciably, and the process is unsuitable for application to springs.

Rolled-on nickel coatings appear to be capable of application to sheets, strip and sections. For special applications the product appears to possess noteworthy advantages.

Other Coatings

Coatings of the phosphate type appear to be capable of affording only a very moderate degree of protection. It seems very doubtful whether any notable advance has been made upon the Coslett type of treatment, in which zinc and iron phosphates are deposited. The treatments are most conveniently applied to small pieces, and the scope of the processes may be compared with that of electro-deposition processes. Although the processes, even when used in conjunction with good paint or enamel, appear to have little, if any, superiority as regards protection against corrosion over similar paint or enamel applied directly to clean steel (*e.g.*, sand-blasted, shot-blasted or descaled), there are advantages from the production point of view. In the first place, the pieces have to be descaled before the treatments can be satisfactorily applied, and any deficiencies in the preliminary cleaning are likely to be detected in the processing. The practical result is that the paint or enamel is applied, where such organic protectives are used, to a surface free from scale and in a more or less uniformly-coated condition. Further, the porous nature of the coatings may prove of value by securing good adhesion of the paint or enamel where the conditions do not permit of the use of a paint possessing intrinsic properties of high adhesion to bare metal surfaces.

Gun blacking is a rather special case in which high resistance to abrasion is generally of great importance. The usual processes appear to give very poor protective qualities from the corrosion point of view, and fail rapidly under relatively mild conditions of exposure unless supplementary protectives such as oil or grease are used. In this field there appears to be scope for advancement, and in this connection black chromium and electrolytically-blacked zinc may prove capable of useful development.

Temporary preservatives appear to be capable of more extended use and for the protection of steel; those of the lanolin-base type pigmented with slightly-soluble chromates appear to possess outstanding merits. The films are rather soft and are easily damaged by handling, but can readily be restored by a fresh application of preservative at any time.

Duty on Imported Pig-Iron

Two orders made under the Import Duties Act, 1932, removing pig-iron from the free list and restoring an *ad valorem* duty of 33⅓ per cent., which was temporarily suspended in March, 1937, were approved by the House of Commons on June 2.

Some Factors in Sand Testing

By T. R. WALKER, M.A.

(*Concluded from page 456.*)

Influence of Drying

The strength of a sand mixture containing a few per cent. of water increases greatly when it is dried, the dry strength depending on the water content in the green state, an increase in which gives an increase in the dry strength. The dry strength also depends on the relative density, and increases as the relative density is increased. At the same time, the conditions during drying and subsequent cooling influence the results obtained. Evaporation of water can, of course, take place at any temperature, if the tension of water vapour in the space surrounding the specimen is maintained at a low value.

Consequently, a sand cylinder may be dried at the ordinary temperature in a vacuum, where the water vapour produced at the surface is immediately removed from the enclosure by a pump, or it may be dried in a desiccator, where the water vapour is removed less rapidly by absorption in, for example, calcium chloride. In the case of the desiccator, the rate of drying is governed by the gradient of water content existing between the outside layers and the interior of the sand cylinder. The advantage of heating

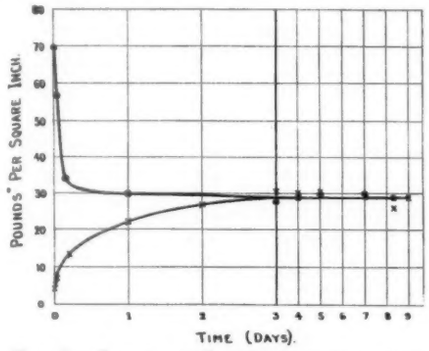


FIG. 3.—GREEN AND DRY STRENGTHS OF SAND MIXTURE CONTAINING 3 PER CENT. WATER.

sand to a few degrees above 100 deg. C. is that at 100 deg. C. under atmospheric pressure water boils, and is consequently quickly removed from all parts of the sand reaching that temperature. The fact that higher temperatures, up to and sometimes exceeding 200 deg. C., are actually used in drying moulds is due to the economic necessity of ensuring that the centre of the mould reaches at least 100 deg. C. in a reasonable time, to make certain that the whole of the mould is dried.

Since the dry strength of a given sand mixture after drying is determined by the water content in the green state, one would expect the

TABLE IV.—*Dry Strength in Compression of King's Lynn Red Silica Sand with 3 per cent. of Bentonite. Dried in Different Ways.*

Method of drying.	Time of drying. Hrs.	Temperature. Deg. C.	Dry strength. Lb. per sq. in.
In vacuum ..	5½	17	33.8
In desiccator ..	10 days	17	33.3
In oven ..	2	105	34.1
In oven ..	1	200	34.1

Water content in green state 3.0 per cent. Relative density 1.6.

dry strength obtained after drying a particular sand of a given water content to be the same, whatever the temperature and conditions of drying.

This is supported by the figures given in Table IV, which gives the strength of cylinders made of the same sand mixture as the cylinders for Tables II and III, dried in different ways.

It must be emphasised that the crushing of all these specimens was carried out at the same temperature, the cylinders heated in the oven being allowed to cool to 17 deg. C. in a desiccator before being crushed.

When sand-clay mixtures are strongly heated, some of the water in the clay is driven off more or less permanently. That is to say, the clay, upon cooling, will not take up water again and regain its original binding power, except very slowly. Some clays begin to lose dry strength at a moderately high temperature. The temperature at which these changes begin to take place varies with different types of clay, and fixes an upper limit to the temperature which should be used for drying. For some clays this maximum temperature is below 200 deg. C. It is thus evident that, if it is desired to select a temperature of drying which will be of general application to various types of sand-clay mixtures, this temperature should not be much above 100 deg. C., sufficient time being allowed at the chosen temperature for all of the specimen to reach the same temperature.

If the figures given in Tables III and IV are compared, it will be seen that the dry strength of the same mixture is higher in Table III than in Table IV. This is accounted for by the difference in the conditions after drying. The cylinders for Table III were removed from the oven and crushed whilst still warm, at 45 deg. C. The cylinders for Table IV were all crushed at 17 deg. C., those which had been heated in the oven being allowed to cool to room temperature in a desiccator before being crushed. As soon as the dried sand cylinder during cooling approaches the temperature of its surroundings, it begins to pick up moisture from the air, a thin film being first absorbed on the outside layer of the cylinder. Subsequently larger quantities are absorbed, the outer layers becoming moister. The moisture gradually moves inwards, thus affecting the interior of the cylinder. It is evident that to measure the full dry strength of a sand mixture, the specimens should be crushed at a temperature sufficiently above that of the surroundings to obviate the picking up of moisture. Consistent but somewhat lower results may be secured by placing the cylinders in a desiccator and crushing at the room temperature.

TABLE V.—*Dry Strength in Compression of King's Lynn Red Silica Sand with 3 per cent. of Bentonite. Allowed to Stand After Drying.*

Dry strength. Lb. per sq. in.	Time of standing.	Moisture content. Per cent.	Average temperature. Deg. C.
40.5	10 min.	—	—
25.3	2 hrs.	0.14	17
21.2	3½ hrs.	0.21	17
16.2	21 hrs.	0.41	17
18.0	2 days	0.41	16
16.2	4 days	0.42	17
16.5	5 days	0.43	16
17.2	7 days	0.41	13
16.9	8 days	0.41	12
16.0	11 days	0.43	12

Dried for 1 hour at 200 deg. C. Water content in green state 3.0 per cent. Relative density 1.6.

Dry Strength Losses on Standing

Table V shows the change in dry strength on standing of cylinders made of the same sand mixture as those for Table II. These cylinders were dried at 200 deg. C. for 1 hr., and then allowed to stand in the laboratory for varying times before being crushed. The first one crushed, after standing for 10 min., was still warm. After this, there is a fall in strength which is very rapid at first, then becomes slower, and finally the strength remains approximately constant. This loss of strength is due to water picked up from the atmosphere and is clearly of great importance, not only in sand testing, but also in foundry practice. To retain the dry strength of large moulds, more particularly the strength of the mould surface, they should be kept hot after drying. After closing and before casting they may be kept warm by passing hot air into them from portable drying stoves, a practice which is already carried out in some foundries.

The figures for green strength given in Table II and those for dry strength given in Table V are shown graphically in Fig. 3. The water content of the cylinders at different stages is given in the Tables, and it will be noticed at once that the strengths indicated do not correspond with the green strength which would be given by milling the dry sand with water to give the equivalent water contents. This is simply because the cylinders which are being allowed to stand, whether they are dry-sand cylinders picking up water or green-sand cylinders losing water, are not uniform throughout. The dry-sand cylinders consist of a dry-sand core with an outside containing an increasing amount of water; the green-sand cylinders consists of green-sand cores with outer layers containing much less water.

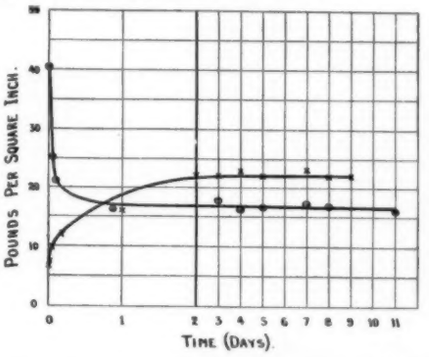


FIG. 4.—GREEN AND DRY STRENGTHS OF SAND MIXTURE CONTAINING 4 PER CENT. WATER.

Since the green strength and the dry strength of a given sand mixture are both affected by the water content in the green state, it is to be expected that the gain or loss in strength on

TABLE VI.—*Green Strength in Compression of King's Lynn Red Silica Sand with 3 per cent. of Bentonite. Allowed to Stand Before Crushing.*

Green strength. Lb. per sq. in.	Time of standing.	Moisture content. Per cent.	Average temperature of surroundings. Deg. C.
4.7	0	4.0	17
5.0	8 min.	3.56	17
7.0	1 hr.	3.12	17
13.4	5 hrs.	1.78	18
22.0	1 day	0.83	17
26.7	2 days	0.74	16
30.4	3 days	0.53	14
30.0	4 days	0.44	14
30.4	5 days	0.45	14
29.3	7 days	0.48	13
25.7	8 days	0.50	12
28.4	9 days	0.46	14

Original water content 4 per cent. Relative density 1.6.

standing will be influenced by the original water content in the green state. That this is so is illustrated by the figures in Tables VI and VII. Table VI shows the change in green strength of a sand mixture similar to that used for Tables II, III, IV and V, but originally containing 4 per cent. of water. The green strength is initially lower than that given by

a similar mixture containing 3 per cent. of water, but on standing the cylinders reach a higher strength than those originally containing 3 per cent. of water.

Table VII gives the corresponding dry strength of cylinders allowed to stand after drying and before crushing. The original dry strength is

TABLE VII.—*Dry Strength in Compression of King's Lynn Red Silica Sand with 3 per cent. of Bentonite. Allowed to Stand After Baking.*

Dry strength. Lb. per sq. in.	Time of standing.	Moisture content. Per cent.	Average temperature of surroundings. Deg. C.
70.0	12 min.	—	—
57.0	50 min.	0.04	17
34.0	4 hrs.	0.13	18
29.9	1 day	0.29	17
27.3	3 days	0.34	16
28.3	4 days	0.31	14
29.4	5 days	0.32	14
29.7	7 days	0.33	14
28.5	8 days	0.35	12

Dried for 1 hr. at 200 deg. C. Water content in green state 4.0 per cent. Relative density 1.6.

higher than for the mixtures containing in the green state 3 per cent. of water, and though it decreases considerably, it does not fall to the values given by the cylinders from the latter mixture. In this particular case the final strengths of both the dried and green cylinders are about the same. The figures for Tables VI and VII are shown graphically in Fig. 4.

Need for Standardisation

It is evident from the above experiments that, whilst it is comparatively easy for a single worker, carrying out tests according to his own procedure, to obtain consistent figures for the green and dry crushing strength of sand mixtures, the experimental conditions must be specified in detail and rigidly adhered to if accurate results are to be obtained, or if it is desired to compare the results of the work carried out by investigators in different laboratories.

Mechanical Grading

The separation of a sand into particles of different sizes, that is to say, the mechanical grading of the sand, is another form of sand examination which presents considerable difficulties when attempts are made to correlate the work of investigators in different laboratories. The operation may be carried out by sieving, if the sand consists of silica grains with no adhering clay. If the sand is a moulding sand, either naturally bonded or synthetically bonded with clay, the clay must be loosened by boiling the sand in a dilute alkaline solution such as a 2 per cent. ammonia solution and washing repeatedly until all the clay is removed. The separation of the dry sand into particles of different sizes may then be carried out by sieving, down to a particle size of 0.1 mm.

Unfortunately, at present there are no sieves which are accepted as standard throughout the world. Sieves are named according to the number of apertures per inch or per centimetre of sieve length, but the actual size of the opening is governed by the diameter of the wire used for making the sieves. In America, Tyler sieves have been adopted as standard for sand testing purposes. In Great Britain the sieves given in Table I of the British Standards Institution Specification No. 410, of 1931, have been adopted as standard by the technical committees concerned in sand testing. These two kinds of sieves, however, are not constructed to give the same ratio of aperture per centimetre length of sieve, so that the results obtained by sieving a sand in the two kinds of sieves are not directly comparable, even when sieves of the same nominal mesh are used in each case.

International Differences

Apart from this, the series of Tyler sieves recommended by the American Foundrymen's Association does not agree with the list of British Standards Institution sieves recommended by the British sand-testing committees, as will be seen from Table VII.

TABLE VIII.—*Lists of Sieves Recommended for Sand Testing.*

B.S.I. sieve No.	Side of aperture. Ins.	A.F.A. sieve No.	Side of aperture. Ins.
—	—	6	0.132
8	0.0810	—	—
10	0.0660	12	0.0661
22	0.0275	—	—
—	—	30	0.0232
30	0.0197	—	—
—	—	40	0.0165
44	0.0139	—	—
—	—	50	0.0117
60	0.0099	—	—
—	—	70	0.0083
100	0.0060	100	0.0059
150	0.0041	140	0.0041
200	0.0030	200	0.0029
300	0.0021	270	0.0021

This lack of agreement between the two lists of recommended sieves makes it very difficult to compare the work of investigators in different countries. The differences in results when the same sand is examined are comparatively small when the sand in question consists of grains which occur in substantial percentages over a wide range of sizes, but become important when sands are examined of which the grains are all of nearly the same size.

Divergent Methods Examined

Even if a list of sieves were agreed upon as standard to be used internationally, the conditions of their use would still need to be closely specified. Sieving may be carried out by hand, or by machines in which a nest of sieves is revolved and agitated mechanically. In the case of hand sieving, a weighed amount of sand is usually placed in a coarse sieve and shaken, either for a given time or until the sand is passing through at less than a predetermined rate, after which the remaining sand is placed in the next finer sieve, and the operation is repeated. In mechanical sieving machines the operation is usually carried out simultaneously, with a vertical nest of sieves, for a length of time which represents a compromise between accuracy and the need for obtaining results quickly.

The results obtained for a given sand vary, not only when the sand machine is used with different times of sieving, but also when different types of machines are used, sieving either for the same time or for different times, even assuming that the same sieves are used in every case. Here, again, it is comparatively easy to obtain consistent results when one operator carries out sieving operations always according to the same procedure, whether hand or machine sieving is adopted, but the correlation of the work of investigators in different laboratories is much more difficult.

The differences in results obtained by varying the conditions of sieving apply more particularly to sieves of small mesh. It will be noticed that both sets of sieves recommended in Table VIII include two of which the aperture is less than 0.1 mm. In practice it is found that the use of such fine sieves gives very inaccurate and misleading results.

The particles less than 0.1 mm. in diameter are best separated by an elutriator, in which an ascending stream of water removes all particles up to a predetermined maximum size, which is fixed by the velocity of the stream of water. It is easy to construct elutriators having the same characteristics, and if separate elutriators are used for removing particles of each desired range of size, accurate results can readily be obtained from the majority of sands. Sands containing mica may give peculiar results both with sieves and with elutriators, as the flat plates of mica do not readily pass through the appropriate sieve, and in the elutriator they fall through water at a lower rate than spheres of equal weight.

Conclusion

New methods of sand testing, involving new types of apparatus, are continually being put forward as suitable for testing the properties of sand in some novel way. The present Paper deals only with the determination of the strength in compression and the separation of sand into particles of different size. These are generally regarded as the simplest tests to carry out, but it is evident that to obtain accurate results the experimental conditions of the testing must be closely controlled.

If sand testing is to be of real assistance in the investigation of the fundamental properties of sand mixtures, and the correlation of these with the foundry behaviour of sands, it is essential that the results obtained from a given sand by one investigator be reproducible by another investigator in a different laboratory, or even in a different country, since it is only by the intelligent co-operation of groups of workers that substantial progress will be made. When this has been made possible for simple determinations such as those of strength in compression and the distribution of particle size, the critical examination of other methods of testing will be greatly facilitated, and sand testing will be established on a sound scientific foundation.

Some Physical Factors in Casting High-Strength Brasses

(*Concluded from page* 481.)

casting is covered by a thin film of aluminium oxide, a poor conductor of heat.

Whilst no attempt has been made in this Paper to describe the methods adopted in laboratories to determine the values of the properties discussed, it has been shown, it is hoped, that these physical factors have a very real practical bearing on some of the problems encountered in non-ferrous foundries.

The whole question of successful casting in all the commercial non-ferrous alloys is closely related to the thermal history and behaviour of the metal throughout the melting, casting and cooling cycle, and such properties as specific heat and latent heat of fusion, varying widely from system to system, cover a much greater range than in the ferrous alloys.

In some instances, a high specific heat, which may call for special measures in the foundry, may be one of the valuable assets of the finished casting, as, for example, large aluminium alloy pistons for internal-combustion engines, where high heat capacity without large temperature increase is desirable.

It is pleasing to note that the lack of information on some of these properties is now recognised, and that work is proceeding at such institutions as the National Physical Laboratory, and will become available to the industry.

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Heat-Treatable Aluminium-Silicon Casting Alloys*

By GASTON G. GAUTHIER†
[FRENCH EXCHANGE PAPER]

Summary

The author gives some of the results obtained in the course of researches made by the laboratory of the Compagnie Alais, Froges & Camargue on heat-treatable aluminium-silicon casting alloys containing in addition magnesium, manganese or cobalt.

Tables give the variation of the mechanical properties under the influence of the heat-treatments and under the influence of variations in the contents of Si, Fe, Mg, Mn, Co and Na.

It is not the purpose of this Paper to give new results. The alloys under discussion have been known since 1931, and much work has been done on them. The author's intention is simply to group the figures obtained in the course of extensive investigations made in the laboratory of the Compagnie Alais, Froges & Camargue, and to provide in this way comprehensive information useful to foundrymen and designers.

Ever since they have been in use, the alloys containing 13 per cent. silicon, modified by means of sodium and called Alpax or Silumin, depending on the country, have undergone considerable industrial development by reason of their casting properties, in other words, their excellent mould-filling capacity and the faithfulness with which the finest details are reproduced.

For manufacturing these alloys, their inventor, Aladar Pacz, endeavouring to utilise an aluminium of the lowest possible quality as base, very soon perceived that above 0.8 per cent. iron the elongation of these alloys rapidly drops, and he was led to investigate the means for obviating this disadvantage, due to the formation of flat, brittle crystals of a compound of aluminium, iron and silicon. As early as 1920, he took out patents for additions of manganese, cobalt, chromium, etc. These additions certainly had the effect of refining the grain of alpax of high iron content, and of considerably increasing the mechanical properties in alpax of normal iron content. The tensile strength remained below 20 kg. per sq. mm., the elongation attained at the most 10 to 12 per cent., and the elastic limit at 0.02 per cent. elongation remained in the region of 5 to 7 kg. per sq. mm., according to the quality and quantity of the additions made.

It was not until 1931 that an appreciable advance was made in this class of alloys by the appearance of heat-treatable alloys, the hardening component of which is a small quantity of the compound Mg_2Si. For counteracting the effect of the iron, one of the elements previously indicated by Pacz for this purpose is added, as well as the addition of magnesium. The latter has the effect of causing the formation of flat, brittle crystals of alloy rich in iron and silicon, so that for such alloys it would be necessary to employ very pure aluminium and silicon as base, which would be a serious disadvantage. The additions of manganese and cobalt for counteracting this detrimental influence are the two additions which up till now have been most investigated and are the only ones which have been adopted in industrial practice.

The typical alloy contains approximately:—Si, 9 to 12.5 per cent.; Mg, 0.25 to 0.35 per cent.; Fe, $<$0.5 per cent.; with either Mn 0.3 to 0.5 per cent. or Co 0.4 to 0.6 per cent.

In this Paper, it is intended to deal successively with alloys containing manganese and alloys containing cobalt.

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General Remarks

The investigations were made on sand-cast and chill-cast specimens, but only the results obtained on sand-cast specimens will be given in what follows. Casting in sand was effected with the use of green sand, that is to say, sand containing about 5 to 6 per cent. moisture. The mould carried two specimens connected together at both heads by channels. At one end of these channels is a gate, which has the form of a saw-tooth roof for retaining the dross, and at the other end is the feeding head. The pouring temperature was always uniformly between 700 and 720 deg. C. The test specimens were about 15 mm. in diameter, and, after machining, the useful part was reduced to a diameter of 13.8 mm. and to a length of 105 mm., in order to measure the elongation on 100 mm.

MR. GASTON G. GAUTHIER.

All the melts (excepting, of course, those used for investigating the influence of small amounts of sodium) were subjected to an addition of sodium by the process known as "double modification." The bath of molten metal is provided with a surface layer of 0.3 per cent. of a mixture of 66 per cent. of NaCl and 33 per cent. of NaF as soon as its temperature reaches 750 deg. C. At 780 deg. C., 0.05 per cent. Na is introduced by means of a perforated bell-shaped tool. The metal is allowed to cool, and the samples are cast, as stated above, between 700 and 720 deg. C.

The specimens for the notched-bar impact test were made from the above samples, being machined on all faces. They were of square section of 10 by 10 mm., length 55 mm., and the notch was 2 mm. deep and 2 mm. wide (Mesnager specimen). The fatigue test specimens were machined from castings 20 mm. in diameter and of sufficient length, the dimensions being those laid down by the French Aircraft Standards for Alkan machines.

For the heat-treatments, an electrically-heated muffle furnace with temperature-regulating means was used for the heating before quenching. On leaving the furnace, the specimens were very rapidly plunged into cold water at 20 deg. C., so as to avoid 5 secs. at the most elapsing between the opening of the furnace and the quenching of the samples. Heating for age-hardening was carried out in an oil-bath, the temperature of which was controlled with the aid of a thermometer.

TABLE I.—*Influence of Temperature of Heating before Quenching.*

	Temperature of heating.				
	520 deg. C.	530 deg. C.	540 deg. C.	550 deg. C.	565 deg. C.
Tensile strength, kg. per sq. mm. ..	28.7	29.2	29.0	29.5	27.5
Elongation, per cent. ..	1.75	2.0	2.0	2.25	1.75

Plan of Discussion

For each of the alloys containing manganese or cobalt, the same plan of discussion will be adopted, as follows:—First of all an account will be given of the investigations made for perfecting the heat-treatment and of the variations in the properties depending on the heat-treatment, and after that the influence exerted on the properties by slight variations in the different additions for the heat-treatment adopted will be reviewed.

ALLOYS WITH THE ADDITION OF MANGANESE

Heat-Treatment

(A) *Quenching.*—The influence of the duration and temperature of heating before quenching was examined for numerous casts of the same composition, containing approximately:—Si 12.5, Mg 0.25, Mn 0.45, and Fe 0.35 per cent.

First of all the influence of the variation of the quenching temperature was investigated in the case of a uniform duration of heating of 10 hrs. Table I gives the results obtained for these various temperatures with specimens which in addition had been subjected to a uniform age-hardening treatment at 155 deg. C. for 24 hrs. This table clearly shows that the temperature of 565 deg. C. is too high.

TABLE II.—*Influence of Duration of Heating before Quenching.*

Temperature.	Duration of heating.							
	3 hrs.		4½ hrs.		6 hrs.		10 hrs.	
	T	E	T	E	T	E	T	E
540 deg. C. ..	28.5	2.5	28.7	2.0	28.9	2.0	29.0	2.0
550 deg. C. ..	29.3	2.0	30.2	2.0	29.0	1.5	30.0	2.25

T = Tensile strength, kg. per sq. mm. E = Elongation, per cent.

For fixing the duration of heating before quenching, the mechanical properties attainable on specimens heated respectively for 3, 4½, 6 and 10 hrs. and then quenched were investigated for several temperatures below 560 deg. C. All the specimens were then subjected to a uniform age-hardening treatment at 155 deg. C. for 24 hrs. Table II gives these results for the temperatures 540 and 550 deg. C.

Consideration of Tables I and II permits one to say that the quenching temperature to be adopted for industrial practice may be fixed between 540 and 550 deg. C., according to the

precision of the temperature-regulating device. The duration of heating may be fixed at 6 hrs., because the gain in properties obtained by prolonging the treatment is only very slight. Such a duration of treatment is relatively short and is satisfactory in practice.

(*B*) *Age-hardening Treatment.*—Employing the same lot of alloy as for the above tests, an investigation was also made to determine the age-hardening conditions. For this purpose, a batch of specimens was heated for 6 hrs. at 540 deg. C., quenched in cold water and subjected to an age-hardening treatment of varying duration and temperature. The chief results of practical interest have been reproduced in Table III, from which it may be gathered that various combinations of temperature and duration giving appreciably the same results can be selected. In practice, the temperature of 160 deg. C. has been adopted, this corresponding to a heating period of 10 hrs., because in these conditions a slight deviation either of temperature or duration of heating only produces a very slight modification in the resulting properties, this being a very important point.

It may be observed that up to 135 deg. C. the influence of age-hardening on the reduction of elongation is slight, which may be advantageous for certain applications of the castings, for example for small castings which are subsequently subjected to deformation stresses during assemblage (riveting, for example).

In all the tests to be described below, the following heat-treatment was adopted:—heating for 6 hrs. at 540 deg. C., quenching in cold water, age-hardening for 10 hrs. at 160 deg. C.

TABLE III.—*Influence of Temperature and Duration of Heating for Age-Hardening.*

Temperature. / Duration in hours.	As cast.	Quenched, non-age-hardened.	125 deg. C.			135 deg. C.			145 deg. C.			155 deg. C.			165 deg. C.			175 deg. C.		
			5 hrs.	10 hrs.	20 hrs.	5 hrs.	10 hrs.	20 hrs.	5 hrs.	10 hrs.	20 hrs.	5 hrs.	10 hrs.	20 hrs.	5 hrs.	10 hrs.	20 hrs.	5 hrs.	10 hrs.	20 hrs.
Tensile strength, kg. per sq. mm.	18.1	22.8	23.8	23.9	24.5	24.8	25.4	26.9	25.2	26.5	29.5	26.5	28.7	29.4	29.0	28.7	27.8	28.4	28.0	28.0
Elongation, per cent.	4.25	4.0	5.0	4.7	4.5	4.5	4.2	4.0	4.5	4.2	3.0	3.5	3	2	2.2	1.7	1.0	1.5	0.7	0.5
Brinell hardness ..	66	90	90	92	97	—	98	105	95	97	105	96	105	107	103	105	106	110	100	97

nfluence of the Silicon Content

Table IV shows the effect of varying the silicon content between 8.5 and 12.5 per cent. on the tensile strength, elongation, elastic limit at 0.02 per cent. of the permanent elongation, fatigue strength by reversed bending tests and hardness. It is found that the increase in the silicon content increases the tensile strength and also the elastic limit and hardness. The fatigue strength, on the contrary, appears to pass through a maximum between 9.5 and 11.5 per cent. silicon. This latter result may be explained as being due to the disappearance of the last primary crystals of silicon, which, being more brittle than the matrix of the alloy, are probably the seat of "notch effects," thus inducing premature fracture.

TABLE IV.—*Influence of Silicon.*

Si. Per cent.	Tensile strength. Kg. per sq. mm.	Elongation. Per cent.	Elastic limit 0.02.	Fatigue strength.	Brinell hardness.
8.5 ..	25.6	2.0	13.0	7.25	89
9.5 ..	25.0	2.0	13.2	7.25	90
10.5 ..	25.8	2.2	13.5	7.5	95
11.5 ..	28.0	2.5	14.0	7.25	97
12.5 ..	28.2	3.0	16.0	7.0	103

The notched bar impact figure is almost constant for all these alloys and is about 0.40 kg. per sq. cm.

The flowing power or "life" of the alloy is measured by the length of metal it is possible to obtain on pouring the alloy at 700 deg. C. in a spiral mould. The result of the test shows that this property tends to diminish slightly with decrease in the silicon content. For 9 per cent. Si, the "life" is 80 per cent. that of an alloy containing 12 per cent. Si.

From the examination of these properties, it follows that if castings are to be subsequently subjected to alternating stresses, it will be necessary to make them of an alloy having a silicon content in the vicinity of 10 per cent. in order to be within the zone of maximum fatigue strength. In this case, there may be some slight additional difficulties in the foundry, due mainly to the formation of "pinholes," but this slight disadvantage is of little importance compared with the advantage of the improved behaviour of the casting in service. Where castings are not to be subjected to excessively severe alternating stresses, it will be preferable to cast with an alloy having about 12.5 per cent. silicon, so as to ensure a combination of high elastic limit, tensile strength and hardness.

Influence of the Magnesium Content

Table V gives the mechanical properties resulting from a variation in the magnesium content between 0.15 and 0.75 per cent. in alloys containing approximately Si 12.4, Fe 0.4, and Mn 0.5 per cent. In addition to the properties of the metal treated as above, this table also gives the properties of the metal as cast, because in this condition the influence of the magnesium is almost the same as on an alloy without manganese. As will be seen, the effect of magnesium is to increase the tensile strength, elastic limit and hardness, and to diminish the elongation very considerably, this latter effect being proportionally much more marked on the treated alloy than on the alloy as cast. These results permit the most appropriate magnesium content to be fixed as follows. Bearing in mind that from 0.25 to 0.35 per cent., the increase in the tensile strength is relatively slight as compared with the diminution in elongation (resulting in brittleness), the maximum content will be fixed at about 0.30 per cent. More exactly, this content will be fixed at 0.25 ± 0.03 per cent.

As is to be feared, upon each re-melting of scrap (runners, risers, etc.), chemical analysis, or better still spectrographic analysis, reveals a loss of magnesium. In the case of re-melts comprising only small pieces of scrap weighing a few hundred grams, this loss may be put at an average of about 15 per cent. of the content. A very appreciable drop in the mechanical properties would follow if scrap only was employed. Fortunately, it is usual in the foundry to employ both new metal and scrap, the proportion being approximately slightly more than one-third of scrap for slightly less than two-thirds of new metal. To allow for the loss of magnesium, therefore, it is merely necessary either to employ a new alloy containing slightly more than the normal content of magnesium or to add magnesium or intermediate magnesium alloy to each melt.

TABLE V.—*Influence of Magnesium.*

Mg. Per cent.	Specimens as cast.		Treated specimens.			
	Tensile strength. Kg. per sq. mm.	Elongation. Per cent.	Tensile strength. Kg. per sq. mm.	Elongation. Per cent.	Elastic limit 0.02.	Brinell hardness.
0.15	18.2	5.0	27.8	3.0	16.0	95
0.25	17.7	4.0	28.3	2.0	17.0	103
0.35	17.6	3.7	28.9	1.2	19.0	112
0.50	16.5	2.7	31.4	0.3	21.0	118
0.75	15.6	1.7	31.5	0.3	22.5	128

In addition, it must be remarked that in the course of the heating prior to quenching, the surface of castings loses some of its magnesium (by oxidation and possibly by volatilisation), resulting in two facts:

(*a*) Reduction in the hardness of the surface layer: It is merely necessary to remove half a millimetre of metal to find a normal Brinell hardness again. The mean difference found is 10 to 15 Brinell units. This should be taken into account in reception tests.

(*b*) Inherent protection of castings against corrosion, the surface layer serving as protective layer on account of its low magnesium content.

Influence of the Quantity of Sodium

As stated above, all the foregoing results were obtained on cast specimens which had been subjected to "double modification," as described in the section headed "General Remarks," because maximum tensile strength, and, above all, maximum elongation, were obtained under such conditions. The following experiments showed the influence which small quantities of sodium are able to exert on the mechanical properties (Table VI).

In each case, about 33 lbs. of alloy were melted from a batch of known composition, and for the first four melts 0.3 per cent. of the mixture NaCl 66 per cent. and NaF 33 per cent. was added at 780 to 800 deg. C. Then, after the lapse of 5 min., decreasing quantities of sodium were added at 780 deg. C. In two other melts, modification was effected with sodium without the previous addition of salts.

It will be seen that good properties cannot be secured in the absence of salts. The action of the latter must probably be that of degassing the molten metal before the introduction of the sodium. In addition, it is clear that at least 0.05 per cent. sodium must be added.

The presence of sodium increases the elongation and to a slight extent also the tensile strength and hardness. It may, furthermore, be

TABLE VI.—*Influence of Sodium.*

Sodium added. Per cent.	Properties of treated alloy.		
	Tensile strength. Kg. per sq. mm.	Elongation. Per cent.	Brinell hardness.
	With addition of salts.		
0.05 ..	28.6	3.0	108
0.025 ..	27.6	1.75	100
0.0125 ..	24.8	0.75	100
0	24.3	0.5	98
	Without addition of salts.		
0.025 ..	27.0	1.2	100
0.0125 ..	25.4	0.75	95

observed that casts which have been subjected to double modification possess fewer "pinholes" than the others. This is due to the degassing action of the salts thrown on the surface towards the end of melting

Influence of Manganese

The action of manganese in Al-Si alloys is to transform the brittle lamellar crystals of Al-Fe-Si into crystals of compact and less brittle form. The manganese thus exerts two effects which contribute in achieving the same object. By diminishing the surface of crystals rich in iron, it reduces the importance of the slip planes, while in addition it reduces the brittleness of these crystals rich in iron. It will be appreciated that the manganese content to be adopted for an alloy depends almost entirely upon the iron content.

TABLE VII.—*Influence of Quenching Temperature.*

	Temperature of heating.				
	540 deg. C.	550 deg. C.	560 deg. C.	565 deg. C.	570 deg. C.
Tensile strength, kg. per sq. mm. ..	28.5	29.0	29.5	26.5	26.0
Elongation, per cent. ..	3	4.2	2.7	1	0.6

In practice, the iron content is less than 0.5 per cent. An addition of 0.4 to 0.5 per cent. Mn is therefore sufficient for the latter to exert its full effect. Tests show, moreover, that a variation between 0.25 and 0.5 per cent. Mn in an alloy containing 0.5 per cent. iron only very slightly affects the properties of the alloy. The content of 0.5 per cent. Mn will therefore be adopted, so as to allow for the possibility of an addition of iron which may always occur in the course of the manipulation of the alloy in the foundry.

Influence of Iron

Although in Al-Si alloys without additional components, but which have been modified by means of sodium or sodium salts, at least 0.7 to 0.8 per cent. iron is necessary to cause the appearance of crystals of Al-Fe-Si, these crystals appear in alloys containing magnesium for quite low contents, if there are no other additions, such as manganese. It may be said that from 0.3 per cent. these crystals are very clearly visible in micro-sections. In such circumstances, an addition of 0.25 per cent. manganese is sufficient to transform them. In the presence of 0.4 to 0.5 per cent. manganese, at least 0.7 per cent. iron is necessary to cause the appearance of the brittle Al-Fe-Si crystals. This is the content which has been adopted.

TABLE X.—*Influence of Silicon Content.*

Si. Per cent.	Tensile strength. Kg. per sq. mm.	Elastic limit 0.02.	Elongation. Per cent.	Brinell hardness.
7 ..	28.5	17	6	90
8 ..	29.0	19	5	95
9 ..	30.3	21	5	105
11 ..	30.3	22	5	108

ALLOYS WITH ADDITION OF COBALT

As already indicated by Pacz for Al-Si alloys without any additions, about 1920 (French patent No. 523,665), cobalt has an even greater transformation action than manganese on the lamellar and brittle crystals of the compound Al-Fe-Si, and it was therefore natural to think that the manganese could be replaced by cobalt in the heat-treatable Al-Si alloys with advantageous results.

In the case of these alloys, the general tendency being to use a rather low silicon content in the vicinity of 9 per cent., the author adopted the following mean content (except, of course, when investigating the influence of silicon):—Mg 0.25, Fe 0.4, and Co 0.5 per cent.

Heat-Treatment

(A) *Quenching.*—The results given in Table VII indicate the properties of alloys heated at temperatures between 520 and 570 deg. C. for a uniform period of 10 hrs., quenched in cold water (20 deg. C.), and then all subjected to a uniform age-hardening treatment at 150 deg. C. for 33 hrs. It will be seen that the extreme quenching temperature is below 570 deg. C., because the properties corresponding to that temperature—especially the elongation—are very low, there being incipient fusion. The industrial quenching temperature may be fixed at 550 deg. C. in order to allow for any accidental variation in the temperature regulation.

Table VIII gives the influence of the duration of heating before quenching for the temperatures 545, 550 and 560 deg. C. It will be seen that quenching after heating for 10 hrs. at 550 deg. C. appears to be the most advantageous. A shorter duration of heating fails to give adequate elongation, and, except in the case of extremely well-equipped installations, it is not possible to propose a shorter heating at a higher temperature.

TABLE VIII.—*Influence of Duration of Heating before Quenching.*

Temperature.	Duration of heating.							
	3 hrs.		5 hrs.		10 hrs.		20 hrs.	
	T	E	T	E	T	E	T	E
540 deg. C. ..	—	—	26.5	2.2	27.0	2.2	27.2	3.2
550 deg. C. ..	28.0	1.8	28.2	1.8	29.0	2.5	29.0	3.0
560 deg. C. ..	28.7	2.7	29.2	2.8	30.1	2.9	30.1	3.0

T = Tensile strength, kg. per sq. mm. E = Elongation, per cent.

(*b*) *Age-hardening.*—The age-hardening temperatures were ascertained by treating a fairly large number of batches of samples from different casts which were always quenched in cold water after heating for 10 hrs. at 550 deg. C. Age-hardening was carried out at temperatures between 135 and 170 deg. C. for lengths of time varying from 5 to 33 hrs. Table IX gives the results obtained.

TABLE XI.—*Influence of Magnesium Content.*

Mg. Per cent.	Tensile strength. Kg. per sq. mm.	Elongation. Per cent.
0.15	26.5	5.0
0.25	30.2	3.0
0.35	30.2	1.7
0.50	31.5	0 7

Consideration of this table shows that the maximum tensile strength is only obtained above 150 deg. C., and that it is then necessary to continue the treatment for a period of 33 hrs., a costly operation, owing to the furnaces being engaged for such a considerable length of time and the consumption of heating power. The author has adopted heating for 10 hrs. at 165 deg. C. as giving the best age-hardening treatment.

In the following considerations, the results will always be given on samples subjected to the following combination of treatments: heating for 10 hrs. at 550 deg. C., quenching in cold water, then age-hardening for 10 hrs. at 165 deg. C.

Influence of the Silicon Content

Table X gives the results obtained on treated specimens having a silicon content varying between 7 and 11 per cent., the contents of the other components being maintained at approximately the following figures:—Mg, 0.25; Fe, 0.35, and Co, 0.45 per cent. Between 7 and 11 per cent., the influence of silicon on the increase in the tensile strength and the variation of the elongation is relatively slight. The author is unable to give any definite results regarding the fatigue strength as the investigations are still in progress.

The influence of silicon on the flowing power or "life" is approximately the same as that mentioned for the alloys containing manganese. Consideration of the influence of silicon shows that the content to be adopted may be fixed at about 9 per cent.

Influence of the Magnesium Content

The magnesium content was varied from 0.15 to 0.50 per cent. in alloys containing approximately: Si, 9; Fe, 0.35, and Co, 0.50 per cent.

The results are reproduced in Table XI, which shows very clearly that there is no advantage in magnesium contents higher than 0.25 per cent. As in the case of the alloys containing manganese, the elongation drops rapidly without this considerable drop being compensated by a sufficient increase in the tensile strength. The value of 0.25 per cent. will therefore be adopted as the mean magnesium content for these alloys.

Regarding the losses of magnesium on each remelt, the statements made in connection with alloys containing an addition of manganese are likewise applicable to alloys containing an addition of cobalt, the average loss of magnesium due to re-melting being the same for these two sorts of alloy. The same applies to the loss of magnesium from the surface of castings during the heat-treatment and the consequences of such loss.

TABLE IX.—*Influence of Temperature and Duration of Heating for Age-Hardening.*

Temperature. / Duration of heating.	As cast.	Quenched, non-age-hardened.	135 deg. C.				150 deg. C.				165 deg. C.				170 deg. C.
			5 hrs.	10 hrs.	20 hrs.	33 hrs.	5 hrs.	10 hrs.	20 hrs.	33 hrs.	5 hrs.	10 hrs.	20 hrs.	33 hrs.	10 hrs.
Tensile strength, kg. per sq. mm.	17.7	22.8	22.9	23.0	25.0	26.5	24.5	27.5	28.0	30.0	27.7	29.4	30.2	30.1	30.5
Elongation, per cent.	5.0	6.5	6.5	6.5	6.0	5.0	5.0	5.0	4.0	3.0	4.0	4.0	3.7	3.5	3.0
Brinell hardness	62	73	75	80	90	95	90	98	100	104	100	105	107	107	107

TABLE XII.—*Influence of Sodium.*

Sodium added. Per cent.	Properties of treated alloy.	
	Tensile strength. Kg. per sq. mm.	Elongation. Per cent.
With addition of salts.		
0.05	30.0	2.9
0.025	30.3	3.5
0.0125	29.7	3.2
0	20.0	1.7
Without addition of salts.		
0.025	30.7	2.0
0.0125	27.8	1.1

Influence of Cobalt

As stated above, the action of cobalt on the crystals of the compound Al-Fe-Si is similar to that of manganese. This is quite apparent not only from the results of mechanical tests but also from examination of micro-sections. In such sections etched with 1 per cent. hydrofluoric acid, the Al-Fe-Si crystals appear light blue and are in the form of long needles. Increasing additions of cobalt show that at about 0.4 per cent. Co, the Al-Fe-Si crystals are transformed into more compact crystals, appearing brown in colour and ramified in micro-sections etched as above. At 0.6 per cent., the crystals increase considerably in size and appear darker brown in colour as the cobalt content increases. The dimensions become rapidly very large and above 0.6 per cent. Co, the crystals may attain several millimetres in length.

For this reason, the cobalt content will be kept in the vicinity of 0.45 to 0.50 per cent. because it is extremely likely that the large crystals appearing in the case of the higher contents are prejudicial to securing high fatigue strengths.

Influence of Iron

There is no appreciable difference between the influence of iron in alloys containing an addition of cobalt and that of the same metal in alloys containing an addition of manganese, the slight differences which always exist between any two melts of foundry alloys masking the slight difference, if any, of the influence of the iron.

Influence of Sodium

The tests were carried out exactly as for alloys containing manganese. The results are given in Table XII. Comparison of this table with Table VI shows that less sodium is required for alloys containing cobalt than for alloys containing manganese, when the surface of the metal has been protected during melting by 0.3 per cent. of salts. As in the case of the manganese alloys, protection of the metal during melting by means of salts diminishes the tendency to form "pinholes," probably because the action of the salts is to effect degassing and a sort of deoxidation of the molten bath.

CONCLUSIONS

The heat-treatable aluminium-silicon casting alloys represent a considerable advance over ordinary silicon alloys. The latter merely have the following mechanical properties:—Tensile strength, 18 to 20 kg. per sq. mm.; elongation, 7 to 10 per cent.; hardness, 55 to 60 Brinell, and fatigue strength, 4.5 kg. per sq. mm.; whereas the alloys containing an addition of magnesium and manganese or cobalt have the following mechanical properties:—Tensile strength, 27 to 30 kg. per sq. mm.; elongation, 1 to 4 per cent.; hardness, 90 to 110 Brinell, and fatigue strength, 7.5 kg. per sq. mm.

In addition to their high mechanical properties, these alloys possess casting qualities almost equal to those of ordinary Al-Si alloys, this being an extremely important point. It is true that these properties are surpassed by certain alloys containing copper and titanium, but it is possible to hope that further research will improve the results obtained and that industry will hear more of the Al-Si alloys with hardening additions.

Handbook of Railway Stations

A revised edition of the official "Handbook of Railway Stations" has been prepared and is now ready for issue by the Railway Clearing House. The book consists of 654 pages, contains upwards of 50,000 entries, and gives an alphabetical list of stations, sidings, collieries, junctions, works, etc., on the railways of Great Britain and Ireland, together with the county in which each is situated and the exact geographical position. The accommodation at each station is indicated, showing the tonnage of fixed crane power available, places where coal class and mineral traffic in truckloads is dealt with are shown, and other information given.

Book Review

Elastic Properties of Non-Ferrous Metals and Alloys: Collected Data. By J. McKeown and E. D. Ward. Published by the British Non-Ferrous Metals Research Association, Regnart Buildings, Euston Street, London, N.W.1. Price 6s. (post free).

The need for the collection and survey of data on the elastic properties of non-ferrous metals and alloys is evident to anyone who has searched the literature of this subject. A great supply of information exists for most materials, but it is spread over a wide range of technical literature and is not always easily traced. In addition, when a critical survey is made it is found that much of the information is incomplete and quite unsuitable for purposes of comparison, owing to the omission of details regarding such important factors as the limits of accuracy and sensitivity of the determinations.

For the selection of the results given in this report a large mass of published information was collected, and as a first step this was critically examined and all information which failed to reach a high standard set was discarded. In arriving at this standard, the primary condition laid down was the inclusion of the fullest details on (*a*) the composition of the material; (*b*) its condition as tested—this includes its nature, whether wire, sheet, rod, etc.; (*c*) where relevant, the method of production of the material; and (*d*) the sensitivity of the strain-measuring apparatus used. In addition to information from published sources, some determinations recorded in the Association's own research reports are included.

By far the greater part of the data given here has been obtained from tensile tests, and elastic data obtained in torsion tests, bending tests or more complex tests have not been included. Especially in the aluminium series are cast alloys dealt with. Most of the data are given in the form of tables, but occasionally, where space is saved thereby, graphical representation is used. In addition to data on elastic properties, the tables in a large number of cases contain information on the ultimate tensile strength and elongation of the materials. The metals and alloys included in this report have been divided into groups as follows:—Copper and its alloys (further divided under six sub-headings); nickel, cupro-nickels and nickel alloys (five sub-headings); light metals (aluminium; aluminium alloys; magnesium and alloys); and gold, silver, and platinum group metals. Altogether 219 metals and alloys are tabulated. A list of literature references from which the data were obtained is provided, together with an index.

The Principles of Rational Industrial Management. By James J. Gillespie. Published by Sir Isaac Pitman & Sons, Limited, 39, Parker Street, Kingsway, London, W.C.2. Price 10s. 6d. net.

This book is full of practical hints for experienced officials in factories, engineering shops and foundries, and should be of invaluable service to the uninitiated who are striving to attain such positions. It is a comprehensive work which attempts to take the reader through industrial psycho-analysis, economic principles, co-ordinating factors in industry and explanations of the reasons for failure when management endeavours to function without cognisance of the social and psychological, as well as the economic factors.

There is an abundance of outspoken but constructive criticism of those systems of management which are not self disciplined in the use of their authority, and do not work with a purpose beyond that of finance. It is the author's opinion that scientific method is only a tool of management, an important one no doubt, but its virtue and vice are a reflection on the ability and character of its user. Whilst there is a tendency to labour this point, and exception must be taken to the number of chapters devoted to it, one finds it difficult to criticise, because the arguments put forward are illuminating and instructive. The theme throughout the book is that, wherever management functions, there should be a full knowledge of matters in hand, an education founded on the fundamentals of economics, works and commercial procedures, backed up by common sense, and sense of duty to the whole community from the social point of view. Reference is made to failures of so-called scientific managements who have made the mistake of endeavouring to introduce or use such schemes as time study, bonus payment, etc., for the sole purpose of increasing output, and yet showed lack of knowledge by inefficient administration which did not ensure co-operation from the workpeople concerned.

The author is to be congratulated on the syllabus for management which is given in his attempt to offer a constructive basis for the attainment of his ideal. There is nothing strikingly outstanding in this, except the insistence on the subordination of other industrial purposes to the social purpose, which is not surprising, as this is advocated throughout. The book has many chapters of extreme views, but all are of vital interest to those whose ideal is the maintenance in this country of a rational and amicable understanding between employees and employers.

C. D. P.

A.F.A. Officers Elected

Mr. Marshall Post, vice-president of the Birdsboro Steel Foundry & Machine Company, Birdsboro, Pa., has been elected President of the American Foundrymen's Association. Mr. Henry S. Washburn, president of the Plainville Castings Company, Plainville, Conn., has been elected Vice-President. The following have been elected directors for a term of three years:—Mr. Hyman Bornstein (director, Testing and Research Laboratories, Deere & Company, Moline, Ill.); Mr. H. S. Hersey (vice-president and general manager, the C. O. Bartlett & Snow Company, Cleveland); Mr. F. A. Lorenz, Jr. (vice-president, American Steel Foundries, Chicago); Mr. George A. Seyler (Lunkenheimer Company, Cincinnati); and Mr. David O. Thomas (Bendix Aviation Corp., South Bend, Ind.).

Mr. Post, the new President, has had an extended career in the foundry industry. He began as an apprentice moulder with the American Steel Foundries, Granite City, Ill., and became a journeyman moulder with the Commonwealth Steel Company, Granite City. He later returned to the American Steel Foundries, first as assistant foreman, then as night foreman, and finally as foundry superintendent of the Granite City plant. In 1918, he was made superintendent of foundries of the Marion Steam Shovel Company, Marion, Ohio, but returned to the American Steel Foundries in 1920 as works manager of the Sharon, Pa., plant. Later, he was made works manager of the Thurlow plant, Chester, Pa., of the same company. Since 1925, Mr. Post has occupied his present position.

Cleveland Blast Furnaces Closing

Dorman, Long & Company, Limited, are blowing out four of their blast furnaces at the Cleveland Works. These four furnaces are old units of small capacity which have been in operation owing to the exceptional demands of the last 18 months. The two small coke-oven plants at the Redcar Iron & Steel Works and at Chilton Colliery are also being closed down.

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The Week's News in Brief

Trade Talk

THE SKODA WORKS, Prague, has secured a contract for the supply of 11 locomotives for the Lithuanian State Railways.

THE NEW WORKS at Barrhead, Scotland, of the Yorkshire Copper Works, Limited, are expected to be in full operation shortly.

MEMBERS OF the Keighley Association of Engineers are to visit the works of John Lund, Limited, grinding machine manufacturers, Keighley, to-morrow (Friday).

THE INSTITUTE OF WELDING will hold the fifteenth annual general meeting at the Institution of Mechanical Engineers, Storey's Gate, London, S.W.1, on Thursday, June 30, at 4.30 p.m.

PETTERS, LIMITED, Yeovil, have completed arrangements for launching a new type of light air-cooled general utility engine, which is being manufactured on mass-production lines.

FOSTER, YATES & THOM, LIMITED, Canal Foundry, Blackburn, have received from the Office of Works the contract for the boiler plant at the Blackburn Royal Ordnance Factory, a fuse factory, to be built at Lower Darwen.

A PLAN FOR THE MERGER of two of the principal American producers of alloy and stainless-steel products—the Ludlum Steel Company and the Allegheny Steel Company—is to be considered by the shareholders of the two companies.

DEMONSTRATIONS OF electrical pyrometer equipment and heat-treatment plant by the Foster Instrument Company, Limited, Letchworth, in co-operation with the County Borough of Stockport Gas Department, are to be given at the Industrial Gas Showrooms, Gas Works, Portwood, Stockport, from June 13 to 25.

HAUTS-FOURNEAUX ET FONDERIES DE PONT-À-MOUSSON made a net profit of 13,873,535 fcs. in 1937, against 13,171,004 fcs. in 1936. The dividend on the fully-paid 400-fc. shares is 55.26 fcs., and on the quarter-paid 400-fc. shares 37.26 fcs. During the year the capital was increased from 40,000,000 to 100,000,000 fcs.

ACCORDING TO FIGURES recently made available, in 1926 there were in Canada 238 iron and steel manufacturing plants classified by the Dominion Bureau of Statistics under the heading of "The Castings and Forgings Industry." Of these, 119 were in Ontario; 54 in Quebec; 28 in British Columbia, and 10 in Nova Scotia.

KEITH BLACKMAN, LIMITED, have intimated that, in consideration of the year's satisfactory trade, employees with twelve months' service will receive a bonus equal to a week's wages. This is the tenth successive year such a bonus has been paid. The bonus is in addition to a sum payable under the holidays-with-pay agreement.

ABOUT 100 REPRESENTATIVES of British industrial concerns are arranging to attend the Seventh International Management Congress, which will be held in Washington, at the headquarters of the United States Chamber of Commerce, from September 19 to 23. Over 250 Papers on recent developments in management have been submitted for discussion before the seven groups holding technical sessions.

THE ADAMSON-ALLIANCE COMPANY, LIMITED, with head offices at 165, Fenchurch Street, London, E.C.3, has been formed for the purpose of combining the sales and manufacturing organisations of the steelworks equipment divisions of Joseph Adamson & Company, Limited, of Hyde, Cheshire, and the Alliance Machine Company of Alliance, Ohio, U.S.A.

WILD-BARFIELD ELECTRIC FURNACES, LIMITED, Elecfurn Works, North Road, Holloway, London, N.7, announce that additional premises have been taken adjacent to their works, and equipped as a demonstration room. Here a wide range of standard types of heat-treatment furnaces is installed. Adequate facilities are provided to enable the variety of work which the furnaces are called upon to handle to be dealt with, and the furnaces are at the disposal of any firms interested in extending their heat-treatment plant. The upper portion of the premises is reserved for a new research department nearing completion.

Obituary

MR. GEORGE WHITE, who was for over 30 years a patternmaker with James Howden & Company, Limited, Kinning Park, Glasgow, has died.

MR. J. R. HYDE, managing director of Robert Hyde & Son, Limited, iron, steel and non-ferrous founders, of Stoke-on-Trent and Chesterfield, died last Saturday, at the age of 54. He was a prominent figure in Sheffield engineering circles, and was a Past-President of the Sheffield Branch of the Institute of British Foundrymen. He joined the Institute in 1911, had contributed to the "Proceedings," and received a diploma for one of his Papers. Mr. Hyde was also a member of the Institution of Mechanical Engineers and several other societies.

Personal

DR. C. C. PATERSON has been elected as President of the Institute of Physics.

MAJOR H. B. RIGGALL, a director of Ruston & Hornsby, Limited, has been elected President of the Lincoln Chamber of Commerce.

MR. PETER ALLAN, J.P., who has retired after 65 years' service with Carron Company, where he was departmental head of the patternshop, has been presented with a gold-mounted umbrella by the employees. Mr. James Howie, foreman, has been appointed to succeed Mr. Allan.

CAPT. GLYN M. JONES, who has resigned his position as general manager of the Brymbo Steelworks, Wrexham, to take up an appointment with Guest Keen Baldwins Iron & Steel Company, Limited, Cardiff, has received a number of presentations from the Brymbo steelworkers and staff.

DR. F. W. HAYWOOD, Ph.D., B.Sc., A.I.C., has been appointed to the position of chief metallurgist to Wild-Barfield Electric Furnaces, Limited, to take charge of the new research department nearing completion. Dr. Haywood, at present engaged with I.C.I. (Fertilizer & Synthetic Products), Limited, at Billingham, will commence his duties later in the year.

MR. DAVID C. BRUCE, secretary of the Caledon Shipbuilding & Engineering Company, Limited, Dundee, who has retired, started work in 1875 as office boy to Mr. W. B. Thompson, of Tay Foundry. The business became a limited liability company in 1887 and in 1896 was acquired by the Caledon Company. Mr. Arthur A. Craik, the new secretary, has been with the company for 34 years.

DR.-ING. H.C. WOLFGANG REUTER, general manager of Demag Aktiengesellschaft, Duisburg, celebrates on June 11 what may be termed his industrial jubilee, it being fifty years since he joined Rudolf Bredt, proprietor of the Stuckenholz crane works at Wetter-Ruhr. When Bredt retired from business in 1899, Reuter became sole proprietor of the firm Stuckenholz, and, being convinced that the development of special equipment for iron and steel works left much to be desired, devoted his attention to hoisting appliances, transporting and steelworks plant. In 1906, Reuter amalgamated the firm of Stuckenholz with the neighbouring firm of Märkische Maschinenbau-Anstalt, he himself occupying the position of manager. Three years later, a working agreement was concluded with this firm and its chief competitors, the Benrather Maschinenfabrik A.-G., in Benrath, and the Duisburger Maschinenbau-Aktiengesellschaft, vorm. Bechem & Keetman, in Duisburg, which was followed in June, 1910, by the complete amalgamation of these three firms under the abbreviated name "Demag," of which Wolfgang Reuter became the general manager.

Wills

LEACH, ALBERT, of Keighley, brassfounder	£2,143
CHADBURN, COL. A W., of Castleton, Derby, chairman of the Standard Piston Ring & Engineering Company, Limited, Sheffield...	£71,854
ELLIOT, JOHN, of Cardiff, chairman and managing director of Mountstuart Dry Docks, Limited, chairman of Gould's Foundries, Limited, and chairman or director of other companies	£93,371

Birthday Honours List

In the list of Birthday Honours conferred by the King appear the names of several recipients who are connected with the iron and steel, foundry, and allied trades.

MR. VIVIAN HUGH SMITH, who becomes a baron, is a director of Associated Electrical Industries, Limited.

MR. ANDREW AGNEW, who is to be knighted, is a director of Baldwins, Limited, and the Elba Tinplate Company, Limited.

MR. SAMUEL TURNER, chairman and joint managing director of Turner & Newall, Limited, has been awarded a knighthood.

PROF. A. E. V. RICHARDSON, deputy chief executive officer of the Council for Scientific and Industrial Research, Commonwealth of Australia, has been made a C.M.G.

LIEUT-COL. WILLIAM TOZER, who has been made a C.B.E., is a former Master Cutler. He was one of the youngest men ever to hold this ancient office. He is a member of a well-known Sheffield family for many years associated with the steel industry, through the firm of Steel, Peech & Tozer.

MR. CHARLES HERBERT SMITH, who becomes a knight, is a director of Brown Bros., Limited, Henry Pooley & Son, Limited, James Booth & Company (1915), Limited, John Wilkes, Sons & Mappleback, Limited, John Wright & Eagle Range, Limited, Midland Electric Manufacturing Company, Limited, Radiation, Limited, Smith's Stamping Works (Coventry), Limited, W. & T. Avery, Limited, and W. Canning & Company, Limited.

LORD WEIR, who is one of the new Viscounts, is a director of Imperial Chemical Industries, Limited (and member of the management board), and a director of the International Nickel Company of Canada, Limited (and chairman of advisory committee). He is a member of the Council of the Federation of British Industries and Vice-President of the British Electrical and Allied Manufacturers' Association. Lord Weir has occupied several important positions connected with aviation.

New Companies

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

Poole Foundry, Limited, Thames Street, Poole, Dorset.—Capital £600. Directors: W. E. Stephens and B. E. G. Dore.

Mercia Iron Foundry, Limited.—Capital £100. Directors: W. Watsan, 436, Radford Road, Coventry; and J. Guy.

W. J. Molineux (Foundry Equipment), Limited, 20, Waterloo Road, Wolverhampton.—Capital, £500. Directors: Evelyn M. K. Molineux; R. G. Hanson and W. J. Wilson.

Company Reports

Glacier Metal Company, Limited.—First and final dividend of 6 per cent.

Whessoe Foundry & Engineering Company, Limited.—Dividend of 30 per cent. for the year ended March 31.

Electric Construction Company, Limited.—Dividend of 10 per cent. for the year and a bonus of 2½ per cent.

Forthcoming Events

JUNE 20.

British Non-Ferrous Metals Research Association:—Annual general meeting; annual luncheon at Savoy Hotel, London, at 1 p.m.

JUNE 21-24.

International Engineering Congress:—To be held at the Empire Exhibition, Bellahouston Park, Glasgow.

JUNE 28.

National Physical Laboratory:—Annual visit of inspection of work in progress, from 3 to 6 p.m.

JUNE 30.

Manchester Association of Engineers:—Visit to Hovis Flour Mills, Trafford Park, Manchester, at 7 p.m.

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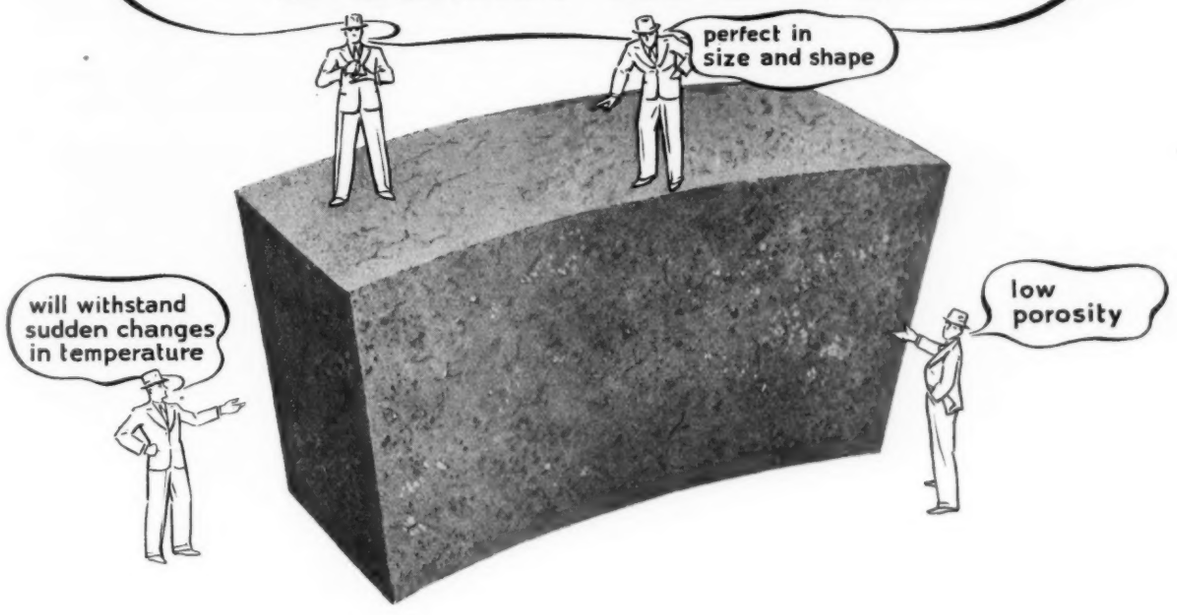

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SWANSEA OFFICE: Metropole Chambers, Wind Street. Telephone: 3680. Telegrams: "Genefax, Swansea." (Mr. D. F. Hood-Williams).

MANCHESTER OFFICE: 9, Albert Square. Telephone: Blackfriars 6130 Telegrams: "Genefax, Manchester." (Mr. S. G. Throssell).

MIDDLESBROUGH OFFICE: Halifax Bldgs., Exchange Place, Telephone: Middlesbrough 3313. Telegrams: "Genefax, Middlesbrough." (Mr. J. A. Williams).

BIRMINGHAM OFFICE: 5, Lower Temple Street, Telephone: Midland 6376. Telegrams: "Genefax, Birmingham." (Mr. G. Griffiths).

Raw Material Markets

The iron and steel markets have remained very quiet since the Witsun holiday. Although makers have intimated that prices of all grades of iron will remain at their present levels until the end of the year, some consumers still seem to be under the impression that there is a possibility of lower quotations before December 31. Users' stocks are heavy and in many branches consumption is still unsatisfactory, so that the need to place further orders is small.

Pig-Iron

MIDDLESBROUGH.—No imported pig-iron has arrived in this area during the past quarter. Consumers are drawing all their requirements from stocks and it should not be very long before additional contracts are entered into. Production is now at a greatly reduced level, but is still considerably in excess of current demands. Makers' stocks, also, are substantial, so there will inevitably be a long break before a return to normal in this respect is made. No. 3 Cleveland G.M.B. iron is quoted at 109s. for delivery in Middlesbrough or Falkirk, with No. 1 foundry at 111s. 6d., and No. 4 foundry and No. 4 forge at 108s., all less 5s. per ton rebate. The demand for hematite is still very quiet. Consumers have substantial tonnages to be delivered before existing contracts have been liquidated. For delivery on the North-East Coast, hematite mixed numbers are quoted at 132s. 6d., 138s. in Sheffield, 140s. 6d. in Manchester, and 140s. 6d. in Birmingham.

LANCASHIRE.—The market has remained very quiet since the holiday, and any new business coming to hand is for small tonnages only. Most of the consuming plants in the Manchester district did not restart work until Monday of this week. Although it is now possible to enter into contracts up to the end of the year, only a small number of orders has been booked for third quarter deliveries. Consumers consider that they have little to gain from making long-term contracts, as supplies are more than sufficient to meet their restricted needs. Textile-machinery makers and the majority of jobbing foundries are badly situated for work, but machine-tool manufacturers and the heavy engineers are satisfactorily employed. For delivery to Manchester and district, Staffordshire and Derbyshire brands of No. 3 foundry iron are quoted on the basis of 114s. per ton, with Northamptonshire No. 3 at 112s. 6d. and Derbyshire forge iron at from 111s. to 113s. The demand for hematite continues to be on the slow side. East Coast material is offered at 140s. 6d., with West Coast at 141s.

MIDLANDS.—The stabilisation of pig-iron prices has only attracted a little extra business, but a few concerns have taken the opportunity to book tonnages over the next quarter. In the circumstances, the majority of consumers are relying on existing contract deliveries or merely ordering small tonnages. Furnaces are well able to make deliveries from stocks, which are accumulating rapidly. Owing to the quietness of trade, most of the light-castings foundries took a prolonged holiday at Whitsun, some not resuming production until Monday of this week. The demand for low-phosphoric iron is satisfactory and consumers are taking up good tonnages. The heavy-electrical engineers, motor-car makers and machine-tool manufacturers are all well employed and in the market for considerable quantities of this type of iron. The price of low-phosphorous iron varies according to the phosphorus content and the railway rate involved; the minimum quotation is £5 15s., while Scottish iron is as high as £7 per ton. The hematite trade is fair, but not many consumers are taking advantage of the opportunity to book supplies up to the end of the year.

SCOTLAND.—Far from making new contracts, pig-iron consumers are endeavouring to keep their deliveries under existing commitments down to manageable levels, as supplies on hand are already more than sufficient to enable them to operate at the required standard. No. 1 foundry iron is quoted at 120s. 6d., with No. 3 foundry at 118s., f.o.t. furnaces. The expected expansion of trade among the light-castings makers has not yet materialised and short time is still general in this branch. Mixed numbers of hematite are quoted at 133s., Scottish basic at 107s. 6d., and English and Indian basic 100s., all less 5s. per ton rebate. Local steelworks are busy and are well covered for pig-iron supplies.

Coke

The lowering of foundry-coke prices has not resulted in much increase of business and most consumers continue to place orders for small tonnages only. For delivery to Birmingham and district, best Durham foundry coke is quoted at 50s. 6d., with Welsh coke at a minimum of the same figure.

Steel

Business in the steel trade since the beginning of the month has developed some of the usual characteristics of the summer period, and the tendency is for the volume of new orders to contract, states the official report of the London Iron and Steel Exchange. This is a customary movement during the second quarter, but in recent years it has been less noticeable, owing to the somewhat abnormal conditions that have prevailed. The heavy stocks which have accumulated in most branches of the consuming trades during the past month or two have contributed to bring about the present position, but in some departments these reserves are being gradually absorbed. In the semi-finished steel section of the market, somewhat similar conditions rule, and the production of this class of material has had to be adjusted to the current needs of the consuming industries. Irregular conditions are noticeable in the finished steel department, but most of the heavy-steel works are operating at a high rate. In the lighter sections there is less activity, and the demand during the past few weeks has been barely maintained. Export business also has been on a restricted scale, but of late the volume of inquiry has shown signs of expansion.

Scrap

In many cases, consumers of iron and steel scrap have temporarily suspended deliveries. Business since the holiday has been almost negligible, and until consumers' stocks have been materially reduced the outlook will remain unsatisfactory. Scotland is undoubtedly the most active district at the present time; steel scrap there is being taken up in good tonnages, but cast-iron scrap is almost entirely neglected.

Metals

Demand for most non-ferrous metals remains very disappointing. Stocks, generally, are accumulating, as production is maintained.

Copper.—This market continues to be the most satisfactory, and fair tonnages are regularly changing hands. Russian and Japanese requirements have been the main factor in keeping this metal in better demand than others, and buying from the latter country has again been substantial during the past few days. The May copper statistics are due to be published shortly, but the German figures may again hold up the completion of the final returns, as they did last month. Customs smelters in the United States have reduced the intake price of scrap to 7 cents per lb.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £34 2s. 6d. to £34 3s. 9d.; Friday, £34 18s. 9d. to £35; Monday, £34 10s. to £34 12s. 6d.; Tuesday, £33 12s. 6d. to £33 13s. 9d.; Wednesday, £33 18s. 9d. to £34.

Three Months.—Thursday, £34 7s. 6d. to £34 8s. 9d.; Friday, £35 2s. 6d. to £35 5s.; Monday, £34 15s. to £34 16s. 3d.; Tuesday, £33 17s. 6d. to £33 18s. 9d.; Wednesday, £34 2s. 6d. to £34 3s. 9d.

Tin.—A surprise announcement that the International Tin Committee will hold its next meeting on June 20 was made on Friday. It is anticipated that the buffer pool will come into operation on July 1. Draft details of the scheme were completed at a meeting of the sub-committee in London last week. Several meetings of important tin-producing concerns have been held recently; views on the buffer pool have been prominently featured in the chairmen's speeches—some favourable to the scheme, while others have contained violent attacks on the proposition. The president of the Billiton Company said that an increase of 7½ per cent. in the standard tonnages of the Netherlands East Indies and Malaya was a justified compensation for those countries. The buffer pool would bring more stable prices; moreover, he expected smaller fluctuations in quotas and more regular production.

Official quotations were as follow :—

Cash.—Thursday, £169 15s. to £170; Friday, £173 to £173 10s.; Monday, £172 5s. to £172 15s.; Tuesday, £170 to £170 5s.; Wednesday, £171 5s. to £171 10s.

Three Months.—Thursday, £170 15s. to £171; Friday, £173 15s. to £174 5s.; Monday, £173 to £173 10s.; Tuesday, £170 15s. to £171 5s.; Wednesday, £172 to £172 5s.

Spelter.—The tone of this market continues to be uncertain. The statistical position, undoubtedly, has weakened, as stocks are plentiful, and production shows no decline. The demand at the present time is quiet, and no indications of any expansion are available. The United States market, also, is very dull; an indication of the falling off in business at the galvanising plants is revealed in the fact that current operations are around 38 per cent. of normal capacity, as compared with about 76 per cent. a year ago.

Daily market prices :—

Ordinary.—Thursday, £12 5s.; Friday, £12 10s.; Monday, £12 6s. 3d.; Tuesday, £12 7s. 6d.; Wednesday, £12 6s. 3d.

Lead.—This market remains very quiet. Production is about maintained, but the demand appears to be declining still further. The American Bureau of Metal Statistics reports that world production of lead during the month of April totalled 147,000 short tons, against 151,100 tons in March. The "Metallgesellschaft" states that the world's smelter output of lead in March was 132,317 metric tons, as compared with 127,304 tons in the previous month.

Day-to-day quotations :—

Soft Foreign (Prompt).—Thursday, £13 2s. 6d.; Friday, £13 12s. 6d.; Monday, £13 8s. 9d.; Tuesday, £13 5s.; Wednesday, £13 6s. 3d.

Scrap.—The turnover in non-ferrous scrap metal was slightly better during the past week, as the result of consumers' desire to cover their immediate requirements owing to the higher quotations for virgin metals.

Approximate selling prices for old metal:—New aluminium cuttings, £75; rolled, £58; cast, £28; foil, £86. Copper, £31 to £34; braziery, £27. Brass (clean), £20 to £23. Zinc, £7. Lead, £11. Gunmetal, £34.

L.C.C. Contract Conditions

The Federation of British Industries has been informed by the London County Council that it has agreed to modify the clause in the L.C.C. contract conditions for engineering works, concerning which the Federation had made representations to the Council. In the clause in question the Council reserved to itself the right to postpone execution of the work for any cause, without granting the contractor recompense for the extra expense to which such postponement might put him. It was believed that actual cases had arisen where such postponements had led to substantial increased cost to the contractor. The Federation contended that the contractor could not possibly foresee or provide for such eventualities over which he had no control.

Corrosion due to Gases

At a conjoint meeting of the Deutsche Gesellschaft für Chemisches Apparatewesen and the Gesellschaft für Korrosionsforschung und Werkstoffschutz on June 9 at Bayreuth, a symposium was held on corrosion due to gases in chemical engineering and its prevention. Prof. Dr. Fischbeck read a Paper on the nature of reactions between metals and gases, which was followed by other Papers: Dr. W. Baukloh dealt with the action of hydrogen on metals, Dr. H. J. Schiffler with corrosion due to gases under the specific conditions of chemical synthesis, Dr. Christmann with the modern manufacture of fixed and mobile pressure tanks and their behaviour as regards liquefied and compressed gases, Dr. H. Brückner with the prevention of corrosion by fine-cleaning of gases, while in conclusion, Dr. W. Wiederholt gave a summary of the subject and the outlook for the future.

SAND PLANT

ROTARY SCREEN
(Covers removed)

CENTRE SHAFT TYPE

CAPACITY 60 tons per hour

with

MAGNETIC BELT CONVEYOR

and

OUTLETS for DESILTING PLANT

SPECIALISTS

Send your enquiries for any FOUNDRY MECHANISATION to the makers:—

COGGON FOUNDRY EQUIPMENT
LIMITED
OVENDEN
HALIFAX

'Phone: 2423.
'Grams: Coggon.

"TICYL"

The NEW All-mine Blast Furnace . . . CYLINDER PIG IRON

ANALYSIS %	
TOTAL CARBON	3·00
SILICON	1·75
SULPHUR	·06
PHOSPHORUS	·15
MANGANESE	1·00

or to suit customers' requirements

G. & R. THOMAS LTD HATHERTON
BLAST FURNACES • BLOXWICH • STAFFORDSHIRE

RAW MATERIALS—PRICE LIST

(Wednesday, June 15, 1938)

COPPER

	£	s.	d.
Standard cash	33	18	9
Three months	34	2	6
Electrolytic	38	10	0
Tough	37	5	0
Best selected	37	15	0
Sheets	70	0	0
India	50	7	6
Wire bars	39	0	0
Ingot bars	39	0	0
H.C. Wire rods	42	10	0
Off. av. cash, May	36	14	$2\frac{5}{11}$
Do., 3 mths., May	36	19	$0\frac{9}{22}$
Do., Sttlmnt., May	36	14	$2\frac{5}{11}$
Do., Electro, May	41	5	$1\frac{4}{11}$
Do., B.S., May	40	15	10
Do., Wire bars, May	41	13	$2\frac{3}{11}$
Solid drawn tubes			$11\frac{1}{2}$d.
Brazed tubes			$11\frac{1}{2}$d.
Wire			$7\frac{1}{2}$d.

BRASS

Solid drawn tubes	$10\frac{1}{2}$d.
Brazed tubes	$12\frac{1}{2}$d.
Rods, drawn	$8\frac{1}{2}$d.
Rods, extd. or rlld.	6d.
Sheets to 10 w.g.	8d.
Wire	$7\frac{1}{2}$d.
Rolled metal	$7\frac{1}{2}$d.
Yellow metal rods	6d.

TIN

	£	s.	d.
Standard cash	171	5	0
Three months	172	0	0
English	171	5	0
Bars	173	5	0
Straits	173	15	0
Eastern	176	0	0
Banca (nom.)			—
Off. av. cash, May	162	16	$8\frac{5}{11}$
Do., 3 mths., May	163	8	9
Do., Sttlmt., May	162	16	$9\frac{3}{11}$

SPELTER

	£	s.	d.
Ordinary	12	6	3
Remelted	9	15	0
Hard	9	5	0
Electro, 99.9	16	3	9
English	13	12	6
India	12	5	0
Zinc dust	17	10	0
Zinc ashes	5	5	0
Off. aver., May	12	15	$6\frac{5}{22}$
Aver., spot, May	12	13	$7\frac{7}{11}$

LEAD

	£	s.	d.
Soft foreign, ppt.	13	6	3
Empire (nom.)	14	2	6
English	15	5	0
Sheets, home	21	0	0
Do. export	17	7	6
Pipes, home	20	10	0
Do. export	18	0	0
Tea lead	29	10	0
Off. aver., May	14	5	$10\frac{15}{88}$
Aver., spot, May	14	4	$2\frac{5}{11}$

ALUMINIUM

Ingots	£100 to £105
Wire	1/3 to 1/4 lb.
Sheet and foil	1/2 to 1/4 lb.

ZINC SHEETS, &c.

	£	s.	d.		£	s.	d.
Zinc sheets, English	26	15	0	to 27	5	0	
Do., V.M. ex-whse.	26	15	0	to 27	5	0	
Rods					18	10	0

ANTIMONY

	£	s.	d.		£	s.	d.
English	70	0	0	to 71	0	0	
Chinese, ex-whse.					52	0	0
Crude, c.i.f.					30	0	0

QUICKSILVER

	£	s.	d.
Quicksilver	13	15	0

FERRO-ALLOYS AND STEEL-MAKING METALS

	£	s.	d.		£	s.	d.
Ferro-silicon—							
25%	12	10	0				
45/50%	12	10	0				
75%	17	0	0				
Ferro-vanadium—							
35/50%	14/- lb. Va.						
Ferro-molybdenum—							
70/75% carbon-free	4/9 lb. Mo.						
Ferro-titanium—							
20/25% carbon-free	9d. lb.						
Ferro-phosphorus, 20/25%	£21 to £22						
Ferro-tungsten—							
80/85%	4/8 lb.						
Tungsten metal powder—							
98/99%	4/9½ lb.						
Ferro-chrome—							
2/4% car.	34	15	0				
4/6% car.	24	5	0				
6/8% car.	24	0	0				
8/10% car.	24	0	0				
Ferro-chrome—							
Max. 2% car.	36	0	0				
Max. 1% car.	38	5	0				
Max. 0.5% car.	41	0	0				
70% carbon-free	10d. lb.						
Nickel—99.5/100%	£180 to £185						
"F" nickel shot	£165	0	0				
Ferro-cobalt, 98/99%	8/6 to 8/9 lb.						
Metallic chromium—							
96/98%	2/5 lb.						
Ferro-manganese—							
76/80% loose	£18	15	0	to 19	5	0	
76/80% packed	£19	15	0	to 20	5	0	
76/80% export	£15	0	0	to 17	0	0	
Metallic manganese—							
94/96% carbon-free	1/3 lb.						

Per ton unless otherwise stated, basis 2-ton lots.

SCRAP

South Wales (West)—	£	s.	d.		£	s.	d.
Heavy steel, best	3	8	9	to 3	11	3	
Mixed iron and steel	3	6	9	to 3	9	3	
Heavy cast iron	3	8	9	to 3	11	3	
Good machinery				3	10	0	
Cleveland—							
Heavy steel, best	3	7	0	to 3	9	6	
Steel turnings	2	13	0	to 2	15	6	
Heavy cast iron				3	10	0	
Heavy machinery				3	15	0	
Midlands—							
Short heavy steel	3	10	0	to 3	12	6	
Light cast-iron scrap				3	2	6	
Heavy wrought iron	4	0	0	to 4	5	0	
Steel turnings	2	6	3	to 2	8	9	
Scotland—							
Heavy steel best	3	5	0	to 3	7	6	
Ordinary cast iron	3	13	6	to 3	15	0	
Cast-iron borings	2	0	6	to 2	3	0	
Wrot-iron piling	3	15	0	to 3	17	6	
Heavy machinery	3	17	6	to 4	0	0	

London—Merchants' buying prices, delivered yard.

	£	s.	d.
Copper (clean)	27	0	0
Brass	17	0	0
Lead (less usual draft)	11	10	0
Tea lead	8	0	0
Zinc	6	10	0
New aluminium cuttings	65	0	0
Braziery copper	23	0	0
Gunmetal	28	0	0
Hollow pewter	120	0	0
Shaped black pewter	80	0	0

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	3s. 0d.
Finished bars, 18% tungsten	3s. 10d.

Per lb. d/d buyers' works.

PIG-IRON*

N.E. Coast (d/d Tees-side area)—	
Foundry No. 1	111/6
„ No. 3	109/-
„ No. 4	108/-
Forge No. 4	108/-
Hematite No. 1	133/-
Hematite M/Nos.	132/6
N.W. Coast—	
Hem. M/Nos. d/d Glas.	133/-
„ d/d Birm.	144/6
Malleable iron d/d Birm.	160/-
Midlands (d/d Birmingham dist.)—	
Staffs No. 4 forge	110/-
„ No. 3 fdry.	111/-
Northants forge	107/6
„ fdry. No. 3	108/6
„ fdry. No. 1	111/6
Derbyshire forge	110/-
„ fdry. No. 3	111/-
„ fdry. No. 1	114/-
Scotland—	
Foundry, No. 1, f.o.t.	120/6
„ No. 3, f.o.t.	118/-
Cleveland No. 3, Glasgow	112/-
„ „ Falkirk	109/-
Scottish hem. M/Nos. d/d	133/-
Sheffield (d/d district)—	
Derby forge	107/6
„ fdry. No. 3	108/6
Lincs forge	107/6
„ fdry. No. 3	108/6
W.C. hematite	138/6
Lancashire (d/d eq. Man.)—	
Derby fdry. No. 3	114/-
Staffs fdry. No. 3	114/-
Northants fdry. No. 3	112/6
Cleveland fdry. No. 3	114/-
Glengarnock, No. 3	137/6
Clyde, No. 3	137/6
Monkland, No. 3	137/6
Eglinton, No. 3	137/6
Gartsherrie, No. 3	137/6
Shotts, No. 3	137/6

(* Prices of hematite and basic pig-iron, and of foundry and forge iron with a phosphoric content of not less than 0.75 per cent., are subject to a rebate of 5s. per ton under certain conditions.)

FINISHED IRON AND STEEL

Usual district deliveries.

[A rebate of 15/- per ton for steel sections, plates and joists is obtainable in the home trade under certain conditions.]

Iron—	£	s.	d.		£	s.	d.
Bars (cr.)	13	5	0	to 13	15	0	
Nut and bolt iron	11	12	6	to 12	2	6	
Hoops				14	2	6	
Marked bars (Staffs) f.o.t.				15	15	0	
Gas strip				14	2	6	
Bolts and nuts, ½ in. × 4 in.				17	10	0 and up	
Steel—							
Plates, ship, etc.	11	8	0	to 11	10	6	
Boiler plts.	11	18	0	to 12	0	6	
Chequer plts.				13	0	6	
Angles				11	0	6	
Tees				12	0	6	
Joists				11	0	6	
Rounds and squares, 3 in. to 5½ in.				12	0	6	
Rounds under 3 in. to ½ in. (untested)				12	4	0	
Flats—8 in. wide and over				11	5	6	
„ under 8 in. and over 5 in.				11	10	6	
Rails, heavy				10	2	6	
Fishplates				14	2	6	
Hoops (Staffs)				12	19	0	
Black sheets, 24g. (4-t. lots)				15	15	0	
Galv. cor. shts. („)				18	10	0	
Galv. flat shts. („)				19	0	0	
Galv. fencing wire, 8g. plain				20	5	0	
Billets, soft, 100-ton lots				7	17	6	
Sheet bars				7	15	0	
Tin bars				7	15	0	

PHOSPHOR BRONZE

	Per lb. basis
Strip	$10\frac{1}{2}$d.
Sheet to 10 w.g.	$10\frac{1}{2}$d.
Wire	$12\frac{1}{2}$d.
Rods	$12\frac{1}{2}$d.
Tubes	$17\frac{1}{2}$d.
Castings	15d.

Delivery 3 cwt. free.
10% phos. cop. £33 above B.S.
15% phos. cop. £38 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	$1/1\frac{1}{2}$ to $1/7\frac{1}{2}$
To 15 in. wide	$1/1\frac{1}{2}$ to $1/7\frac{1}{2}$
To 18 in. wide	1/2 to 1/8
To 21 in. wide	$1/2\frac{1}{2}$ to $1/8\frac{1}{2}$
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to $1/3\frac{1}{2}$
Ingots rolled to spoon size	10d. to $1/6\frac{1}{2}$
Wire round—	
to 10g.	$1/4\frac{1}{2}$ to $1/11\frac{1}{2}$

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, $1/3\frac{1}{2}$ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	25.84
No. 2 foundry, Valley	24.00
No. 2 foundry, Birm.	20.38
Basic, Valley	23.50
Malleable, Valley	24.00
Grey forge, Valley	23.50
Ferro-mang. 80%, seaboard	102.50
O.-h. rails, h'y, at mill	42.50
Billets	37.00
Sheet bars	37.00
Wire rods	47.00
	Cents.
Iron bars, Chicago	2.40
Steel bars	2.45
Tank plates	2.25
Beams, etc.	2.25
Skelp, grooved steel	2.10
Steel hoops	2.40
Sheets, black, No. 24	3.15
Sheets, galv., No. 24	3.80
Wire nails	2.75
Plain wire	2.90
Barbed wire, galv.	3.40
Tinplates, 100-lb. box	$5.35

COKE (at ovens)

Welsh foundry	40/- to 42/6
„ furnace	32/6
Durham foundry	34/6
„ furnace	30/-
Scottish foundry	40/-
„ furnace	35/-

TINPLATES

f.o.b. British Channel ports.

I.C. cokes	20×14 per box		20/3 to 21/6
„	28×20 „		40/6 to 43/-
„	20×10 „		29/-
„	18¾×14 „		21/-
C.W.	20×14 „		19/- to 20/3
„	28×20 „		38/- to 40/6
„	20×10 „		27/-
„	18¾×14 „		19/9 to 20/-

SWEDISH CHARCOAL IRON & STEEL

	£	s.	d.		£	s.	d.
Pig-iron	£11	0	0	to £12	0	0	
Bars-hammered, basis	£20	0	0	to £22	0	0	
Bars and nail-rods, rolled, basis	£19	0	0	to £20	0	0	
Blooms	£18	0	0	to £19	0	0	
Keg steel	£30	0	0	to £35	0	0	
Faggot steel	£19	0	0	to £24	0	0	
Bars and rods dead soft st'l	£13	0	0	to £15	0	0	

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 19.39 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

		£ s. d.	
June	9 ..	34 2 6 dec.	6/3
,,	10 ..	34 18 9 inc.	16/3
,,	13 ..	34 10 0 dec.	8/9
,,	14 ..	33 12 6 ,,	17/6
,,	15 ..	33 18 9 inc.	6/3

Electrolytic Copper

		£ s. d.	
June	9 ..	38 5 0 dec.	5/-
,,	10 ..	39 0 0 inc.	15/-
,,	13 ..	38 10 0 dec.	10/-
,,	14 ..	38 0 0 ,,	10/-
,,	15 ..	38 10 0 inc.	10/-

Standard Tin (cash)

		£ s. d.	
June	9 ..	169 15 0 dec.	30/-
,,	10 ..	173 0 0 inc.	65/-
,,	13 ..	172 5 0 dec.	15/-
,,	14 ..	170 0 0 ,,	45/-
,,	15 ..	171 5 0 inc.	25/-

Tin (English ingots)

		£ s. d.	
June	9 ..	169 15 0 dec.	30/-
,,	10 ..	173 0 0 inc.	65/-
,,	13 ..	172 0 0 dec.	20/-
,,	14 ..	170 0 0 ,,	40/-
,,	15 ..	171 5 0 inc.	25/-

Spelter (ordinary)

		£ s. d.	
June	9 ..	12 5 0 dec.	2/6
,,	10 ..	12 10 0 inc.	5/-
,,	13 ..	12 6 3 dec.	3/9
,,	14 ..	12 7 6 inc.	1/3
,,	15 ..	12 6 3 dec.	1/3

Spelter (Electro, 99.9 per cent.)

		£ s. d.	
June	9 ..	16 2 6 dec.	3/9
,,	10 ..	16 8 9 inc.	6/3
,,	13 ..	16 5 0 dec.	3/9
,,	14 ..	16 5 0 No	change
,,	15 ..	16 3 9 dec.	1/3

Lead (soft foreign, prompt)

		£ s. d.	
June	9 ..	13 2 6 dec.	3/9
,,	10 ..	13 12 6 inc.	10/-
,,	13 ..	13 8 9 dec.	3/9
,,	14 ..	13 5 0 ,,	3/9
,,	15 ..	13 6 3 inc.	1/3

Lead (English)

		£ s. d.	
June	9 ..	15 5 0 dec.	5/-
,,	10 ..	15 15 0 inc.	10/-
,,	13 ..	15 10 0 dec.	5/-
,,	14 ..	15 5 0 ,,	5/-
,,	15 ..	15 5 0 No	change

AVERAGE MONTHLY PRICES OF FURNACE COKE D/D MIDDLESBROUGH

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly average.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1906	0 17 6	0 17 6	0 17 0	0 17 0	0 17 0	0 16 6	0 17 0	0 17 0	0 18 3	0 18 6	0 19 0	1 0 0	0 17 8½
1907	1 4 6	1 5 0	1 5 0	1 0 6	1 2 0	1 1 0	1 1 0	1 1 0	1 2 0	1 1 6	1 0 0	0 17 0	1 1 8½
1908	0 16 0	0 16 0	0 15 6	0 16 0	0 16 3	0 16 0	0 15 6	0 15 6	0 15 6	0 15 3	0 16 0	0 16 0	0 15 9½
1909	0 16 0	0 15 3	0 15 0	0 14 9	0 15 6	0 15 9	0 15 6	0 15 6	0 16 6	0 17 0	0 17 6	0 17 0	0 15 11½
1910	0 18 4½	0 18 6½	0 18 0	0 18 0	0 17 10½	0 17 0	0 16 1½	0 15 9½	0 15 11	0 16 0	0 15 9½	0 15 8	0 16 11
1911	0 16 0	0 15 10½	0 15 6	0 15 3	0 14 9	0 14 6	0 14 6	0 14 6	0 14 6	0 14 6	0 14 11½	0 15 0½	0 16 3½	0 15 1½
1912	0 17 3	0 17 3	0 18 6	0 18 10	0 19 0	0 19 4½	0 19 10½	1 0 9½	1 2 9	1 4 1½	1 5 8½	1 8 6	1 1 0
1913	1 5 9	1 4 11	1 5 0	1 5 0	1 4 9½	1 0 4½	0 19 5½	0 18 3	0 18 0	0 18 2½	0 18 6	0 18 6	1 1 4½
1914	0 18 2	0 17 1	0 17 0	0 17 0	0 17 4	0 17 6	0 17 6	0 18 5	0 18 4	0 17 9	0 17 6	0 18 5	0 17 8
1915	0 17 10½	0 17 9	1 0 4½	1 7 7½	1 9 4½	1 10 7½	1 9 7	1 7 3	1 5 4	1 4 9	1 9 6	1 13 0	1 6 1
1916	1 10 9	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6½
1917	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 10 6	1 14 3	1 15 6	1 11 2½
1918	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6	1 15 6
1919	1 15 6	1 15 6	1 15 6	1 15 6	2 1 6	2 1 6	2 3 9	2 10 6	2 10 6	2 10 6	2 10 6	2 10 6	2 3 5
1920	2 12 3	2 14 0	2 19 0	2 19 0	3 3 8	3 6 0	3 6 0	3 6 0	3 6 0	3 6 0	3 6 0	3 6 0	3 2 6
1921	3 1 0½	2 19 0	2 16 0	2 7 0	2 6 6	2 6 6	2 0 6	2 0 0	1 13 11	1 12 9	1 10 4½	1 8 3	2 3 6½
1922	1 7 0½	1 8 1½	1 9 7½	1 8 4½	1 7 11½	1 7 3	1 6 9½	1 6 10½	1 7 0½	1 10 2½	1 10 0	1 9 11½	1 8 3½
1923	1 11 3	1 14 6	2 0 1½	2 2 8½	2 4 4½	2 2 10½	2 1 0½	2 1 6	2 0 9½	1 18 9	1 18 8½	1 18 3	1 19 7½
1924	1 16 6½	1 14 9	1 11 11½	1 10 0½	1 8 1½	1 7 8½	1 7 3	1 6 3	1 6 0	1 5 0	1 5 0	1 5 0	1 9 5½
1925	1 4 10½	1 4 1½	1 13 3	1 2 4½	1 2 2½	1 1 5½	1 1 3½	1 4 9	0 18 10½	0 18 4½	0 19 6½	1 1 4½	1 2 8½
1926	1 2 1½	1 0 9	0 19 2½	0 18 6½	*	*	*	*	*	*	*	1 5 0	1 1 1½ ‖
1927	1 5 6	1 4 9½	1 6 1½	1 3 9	1 2 6	1 0 8½	0 19 4½	0 19 0	0 18 7½	0 18 0	0 17 10½	0 17 6	1 1 1½
1928	0 17 6	0 17 10½	0 18 0½	0 17 11½	0 17 8½	0 17 6½	0 17 7½	0 17 6½	0 17 6	0 17 7½	0 17 7½	0 17 6	0 17 8
1929	0 17 7½	0 18 0	0 19 0	0 19 6½	0 18 10½	0 19 10½	1 1 3½	1 1 8½	1 3 0	1 3 6	1 3 8	1 3 1½	1 0 9½
1930	1 2 6½	1 1 3	1 0 3	0 19 1½	0 17 7	0 16 10½	0 16 6	0 16 6	0 16 9	0 17 0	0 17 0	0 17 0	0 18 2½
1931	0 17 0	0 16 7½	0 16 0	0 16 0	0 15 11	0 15 5	0 15 1	0 15 0	0 15 0	0 16 9	0 17 0	0 16 6	0 16 0½
1932	0 17 0	0 16 11½	0 16 5½	0 15 9	0 15 7½	0 15 6	0 15 6	0 14 9½	0 14 6½	0 14 6	0 14 6	0 15 4	0 15 6½
1933	0 16 0½	0 15 11½	0 15 6	0 15 6	0 15 6	0 15 6	0 15 6	0 15 8½	0 16 1½	0 17 0	0 17 6	0 18 6	0 16 1½
1934	0 19 4½	1 0 6	1 0 1½	1 0 0	1 0 0	1 0 0	1 0 0	1 0 0	1 0 0	1 0 0	1 0 0	1 0 0	1 0 0
1935	1 0 0	0 19 6½	0 19 0½	0 19 0	0 19 0	0 19 0	0 19 0	0 19 0	0 18 9½	0 18 9½	0 19 5½	1 1 2½	0 19 3½
1936	1 2 0	1 2 11½	1 3 2½	1 4 0	1 4 11½	1 5 3½	1 5 1½	1 4 7½	1 4 6	1 4 6	1 4 6	1 4 6	1 4 1½
1937	1 5 6	1 5 10½	1 7 7½	1 12 9½	1 15 0	1 19 3½	1 18 6½	2 0 0	2 0 3½	2 1 10½	2 2 0	2 2 0	1 16 1½
1938	2 0 1½	1 16 7½	1 16 6	1 16 6	—	—	—	—	—	—	—	—	—

* Strike period. ‖ Five months.

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